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ROCKETS AND REINDEER: THE HISTORY OF THE SWEDISH INNOVATION SYSTEM FOR SPACE AND ITS SPATIAL DIMENSIONS

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Abstract

Given the strength of the Swedish air force and the role of state procurement in industrial expansion, so called development pairs, the size and direction of the non-military but relatively large Swedish space activity raises questions. The purpose of this article is to investigate the historic reasons for Swedish space activities, i.e. research and technology development, with focus on the early period. The relative weight of different policy areas has changed considerably over time. In our analysis the space sector in Sweden has adapted to a multilevel, multi-policy situation and has been instrumental in shaping a science and technology based social innovation system with focus on the Kiruna region.

Prologue

Late in the evening on August 14th 1961, a group of space enthusiasts fired an Arcas rocket acquired from NASA via the Office of Naval Research from Nausta in the military missile field adjacent to Vidsel in northern Sweden. Today, Nausta is most known for the Sirius (1956) and Vega (1957) experiments measuring the impact of nuclear devices of a certain size, but in 1961 those experiments were just as top secret as the Swedish plans to develop nuclear weapons.[1] The Arcas rocket was equipped with a payload of magnesium oxide which was to explode at an altitude of 80 km enabling researchers to study the resulting artificial cloud.[2] So called noctilucent clouds were at this point somewhat an enigma for meteorologists and their investigation was an established line of research within the Stockholm school of meteorology.[3] Even though this particular experiment was hampered by the fact that the payload never exploded and the cloud never materialised, the campaign was viewed a technical and organisational success. Sweden had made her debut in space and Swedish meteorologists had acquired a new tool – space technology.

This episode attracted some media attention,[4] but surprisingly little given that fact that this was the year when Jurij Gagarin circulated the globe in Vostok 1 and Alan Shepard followed him in Mercury 3. This was the year when Kennedy declared his intention to put a man on the moon and bring him safely back to earth.[5] However, this was also a time when missile technology spiced the tensions of the Cold War, something that became frightfully apparent during the Cuban Missile Crisis in October 1962. Technology was serving, as so many times before and after, both the hopes for utopia and the fears of disaster. Sweden had chosen to remain neutral in the division of the world that followed WWII, a neutrality that in time became one of the most salient parts of Swedish identity, and which served as the main motive for fostering a strong defence. How was it then possible to fire a rocket, donated by the US in Lapland, an area of utmost geo-strategic importance?

The sounding-rocket campaign in Nausta and the three following ones in 1962-1964 at Kronogård not far away but on civilian ground were part of an effort to launch Swedish national space activities, which were formally organised in the Space Research Committee in May 1959. The timing had to do with the newly adopted UN resolution, which resulted in a Committee for the peaceful uses of space, into which Sweden had been elected. Central members of the Swedish scientific elite took part, such as Hannes Alfvén, from the Royal Institute of Technology and Bert Bolin, from the Meteorological Institute at Stockholm University (MISU), started in 1947. Bengt Hultqvist, since 1956 director of the Kiruna Geophysical Observatory in Norrbotten county, was made a permanent additional member.[6]
The Committee early decided on three areas of activity. One was to establish a national experiment programme, another to work with the issue of a place for sounding-rocket experiments in Sweden, and a third to take part in international cooperation. Coinciding with the setting up of the Space Research Committee were the attempts to form a European space organisation, what was to become the European Space Research Organisation, ESRO.[7] The Committee soon realised that a national programme would serve a membership in ESRO and vice versa.

Already during the first meetings with the Space Research Committee, different research proposals had been suggested,[8] and the US-government had offered to launch European research satellites at no cost.[9] However, both Alfvén and Bolin had their own contacts in the US through which the Arcas rockets were supplied.[10] The campaign was carried out under the auspices of MISU, responsible for the scientific experiment in question. The Swedish Defence Research Agency (FOA) handled issues of safety and protection. Safety was of course a central question and had been taken very seriously during the whole planning. One safety zone was established around the launching area and another where the rocket and its part would hit the ground. The wind could be no more than 3 m/s and the field had to be cleared of the sami inhabitants. If these requirements were followed, the risk of hitting a person was calculated to $10x10^{-7}$.[11]

The Kronogård campaigns during the summers of 1962, 1963 and 1964 were of another dimension than the Nausta shot. Cost and complexity increased during the three years.[12] Technical know-how was also enhanced, partly through learning by doing and partly through education. In the spring of 1962, seven people from FOA and MISU spent six weeks at the NASA training camp on Wallops Island, Virginia, but also during the following years, part of the technical staff was trained in the United States.[13] The staff was eventually organised as the Space Technology Group, sorting under whatever body presently in charge of the Swedish space activities, a matter that changed over time.

The sounding-rocket campaigns in northern Sweden in the early 1960s were formative in the development of Swedish space activities. The summers were bright not only from a meteorological point of view.[14] However, clouds less beautiful than noctilucent ones would darken the sky and the road to an innovation system for space in Sweden was long and winding.

The favours of perceived emptiness

The Swedish space endeavour could not have been launched in Stockholm, Göteborg, or even Uppsala. The comparative advantage of Kronogård was the empty landscape surrounding it, allowing undisturbed conditions and plenty of space for rockets to land. Or, to be precise, almost empty; a few families had to be moved for every campaign.[15] Kronogård itself was also there, of course, with main building, barn, and several outlying shacks. Kronogård was the unpretentious residence of the state forester with the mission to oversee forestry in the area, which would typically be carried out by colonists, who were allotted state land on long term leases and were expected to carry out some subsistence farming and, principally, do seasonal forest work for wages. Indeed, the crown land colonists were just the last in a series of small waves of colonizers that had arrived, always with state support, mostly tax levies, since the 17th century. The Saami, and small numbers of other hunter-gathering population, had been there long before that. So Kronogård was in fact proof that this part of Lapland was not empty at all, although it was empty enough, as seen from space researchers and the military agencies in Stockholm.

Emptiness was in that respect a resource, one more in a long sequence of resources that have been exploited in Lapland: from fish and fowl to forest, minerals, and hydro-electric power.[16] Emptiness was a valuable resource elsewhere as well. When new dangerous technologies were tested after WWII people could not be too near. The Americans went to atolls in the Pacific to test nuclear bombs, and later on to the desert of Nevada. The Soviet Union made nuclear tests in distant Siberia, Kazchstan, or in Arctic Novaja Zemlja. When NATO needed a test base for missiles and rockets the Norwegians provided Andöya in the Arctic Sea. This spatial logic was more or less the same everywhere. Risk and secrecy demanded that people were not present. In South Australia's red desert a remote little place, christened Woomera, the aboriginal word for a throwing device and geographically almost Lapland's antipode, had since 1946 been the centre of the British government's effort to build a range to test and develop missiles to be used in the expected nuclear arms race with the Soviet Union.[17]

Compared to Woomera Kronogård was located in a rather populated region, which in itself could be seen as a result of a successful welfare state. When the rockets were launched in Lapland Sweden reached its pinnacle of success as an exemplar to the world. Economic growth was strong and Swedish industry beamed with health, having reached a top level of what has been called the "high industrial era".[18] Even Swedish science seemed to be capable of almost anything. In the twenty five years immediately following the war Sweden received five Nobel Prizes in science and medicine only, one of them was the 1970 Physics prize for one of the founding fathers of the space science project, Hannes Alfvén.

This superb performance spread throughout the country. The municipality of Jokkmokk, where Kronogård is situated, has never had a larger population than in the early 1960's. Living standards were on the rise and infrastructure improved through massive state investment. There were forest roads to take out the timber and to connect the small villages and colonist's houses, where the private car was increasingly the norm. This sweeping change in the North was indispensable for the rocket launches. It was not only (a relative) emptiness that facilitated the first Swedish attempt in space, but at least as much the successful spatial distribution of wealth and welfare – and the presence of hi-tech military installations and reserves. After all, Nausta was part of the vast Vidsel testing range, another product of the Cold war, not by far as long as the Woomera corridor, but compared to the size of the country of similar proportions.

The spatial spread of the welfare state was not without costs, however. Forestry and water power projects "industrialized" landscapes brutally, again with parallels in Hinterlands of countries such as Soviet Union, Brazil, and the United States.[19] Probably worst hit were the Saami, whose seasonal migration corridors for the reindeer, organically following valleys, mires, and waters, were blocked by new infrastructure and whose lichen grazing-trees were destroyed by forest clearings. To this massive landscape brutality that was going on for decades, some rocket launches during a few short summer weeks were only a tiny extra intrusion. But the issue had been raised, not in Kronogård but when Esrange was planned in 1961, whether a stray rocket could hit a reindeer, and now, what would that cost?[20] Not that any casualties were likely, but it did not hurt to demonstrate some responsibility towards the local economy. The same issue had been hotly debated in Australia: scattered ranchers fed cows and sheep from the barren lands. The military authorities agreed to build shelters, and a telephone system to alert the farmers. The aboriginals did not get any shelters, nor were they asked for their consent.[21] Was the Saami asked for theirs? At any rate, twenty shelters were finally built around Esrange.

If the Swedish space activities were part of an innovation system, this system also made itself known somewhere. If it existed it must have a geography, a horizontal space, along with the vertical. Both dimensions turned out to be political, because the presence of space means the presence of people. People on the ground are not what innovation systems research is very often about. Innovation systems imply firms, employment, economics, whereas people on the ground raise concerns of risk and a more hands on kind of welfare. To keep the dual perspective on space activities is not as far fetched as it may seem. It had more to do with security than what is commonly believed. In the official history of Swedish space activities, the absence of military connections is striking, as are the aspects of welfare. Indeed, space in Sweden is a story that has been told outside of both warfare and welfare.

So, the question is relevant, why include a chapter about it in this book? Because, we believe, the story that has been told so far has been too limited and can be told in a much more interesting way. Nowhere, it seems, is there any trace of military consideration. Given the fact that, as being pointed out elsewhere in this volume, the Swedish defence, and particularly the Swedish air defence, has been among the strongest in the world, post WWII, the all-civilian space activities are somewhat surprising. Why was this not an area of high-technology development suitable for a warfare state with high aims? Especially in view of the geopolitical position of Sweden in the polar region? Or is the basis for the question wrong? Were there in fact military connections even though they have been downplayed by actors involved and are hard to find in the material? And, if there was military connection somehow, in what relation did it stand towards welfare? After all, in a certain way, warfare and welfare are both to do with security.

And then what about people? If Kronogård was about using emptiness and act as invisibly as possible, today's Swedish space endeavour is about maximum visibility, with the first Swede in space in December 2006 and space being part of a science centre in Kiruna in the far north. What is the road connecting Kronogård with Swedish science and industry? What was the role of government policy and of the European space program? How does the road travelled by Sweden in space fit in the emerging story of post WW II innovation systems? And did everybody on the ground fare equally well?

American Military Links to Swedish Geophysics

The early attempts for Swedish science to reach space were closely linked to the military and to the United States. Air force related science and technology were at the forefront of Swedish-American cooperation, and Meteorology in particular. In Stockholm a new Institute of Meteorology was established after World War II. It was built by and around an American scientific leader, Swedish-born Carl-Gustaf Rossby, the founding father of what came to be known as the Stockholm school of meteorology. After working in the Swedish Weather Institute, the SMHA, and with a licentiate in mathematical physics from the Stockholm Högskola, Rossby moved to the United States where he rose to become a leading meteorological scientist in the 1930's serving first in the US Weather Bureau and later at MIT and at the Woods Hole Oceanographic Institute.

Rossby's military links in the US were impressive. He organized comprehensive training programmes to support the military weather service during the war, and he headed the leading meteorological research school, which was based on military funding and which was located at the University of Chicago. He advised the President and the highest military leadership on weather issues. The demand for improved weather predictions was driven strongly by the military, especially the US Navy and the US Air Force, and also by the atomic warfare authorities, including the Atomic Energy Commission.[22] When atomic testing began in the Pacific after the war, and on the Nevada Test Site from the early 1950's, the nuclear fallout became an issue, and the problem with weather predictions was a constant challenge.[23] All along, Rossby was involved. He was even invited to become the formal head of the Meteorological Project at Princeton, but declined since he was now determined to, unexpectedly, move back to his native in Stockholm, where through swift intervention of influential scientists, the Air Force, and the Swedish government he received a chair of meteorology.[24]

The Meteorological Institute at Stockholm University, MISU, was soon to receive, through sometimes winding institutional roads, substantial funds from American military sources. CIA's Office of Scientific Intelligence, OSI, had in its August 1949 report "The State of Science in Sweden" concluded that Swedish science was of a high standard, and thus contributed to countering the earlier notion that neutral Sweden could be a threat to US ambitions.[25] The US Air Force also concluded that involvement, including funding, in

Rossby's new Institute in Stockholm would benefit the Princeton project. The Princeton project and the new program at MISU were thus essentially linked, institutionally and through their US military funding and through a steady stream of military staff from the US visiting Rossby's Institute.[26]

Rossby mobilized military support in Sweden, connecting with the Air Force in particular.[27] In many organizational ways the Swedish development resembled the American. In 1950 the Swedes started building their own computer, which was crucial for the work on numerical weather predictions, with the Swedish Air Force in an important role.[28] The military dimension of meteorology was both an everyday thing and somewhat of a Red Herring. First of all, neutral Sweden did in fact sustain clandestine connections with the US all along the cold war to an extent that was not disclosed until public enquiries studied this in the 1990's (the Neutrality Commission[29]). Nonetheless, Rossby was cautious to make sure that the funds were "decontaminated" via a civilian institution, e.g., Woods Hole Oceanographic Institution.[30] Even after the demise of the Nordic defence union in the winter of 1949, when Denmark and Norway joined NATO, Norway and Sweden maintained their cooperation in selected areas of strategic interest. One of these areas was meteorology.[31]

Another research environment that benefited from the US military links was the Kiruna Geophysical Observatory, KGO, founded in 1957 as part of the Swedish IGY-effort, and renamed twice to become in 1987 the Swedish Institute for Space Physics (under the, Swedish, acronym IRF). The institute was formed under the Swedish Academy of Sciences and was initially part of the Academy's network of northern research stations.[32] Public funding was made possible as the Institute was made a centerpiece of Swedish IGY planning.[33] The Institute's first director, Bengt Hultqvist at Stockholms Högskola, prepared during the interstice between his PhD exam and his move to Kiruna by following Alfvén's seminars at KTH and by making an extended trip to the United States in the fall of 1956. Among his stops was the Geophysical Institute, College, Alaska, near Fairbanks, where he met with the vice president of the American IGY, Sydney Chapman. Another was the Air Force Cambridge Research Center in Massachusetts, where Rossby had connections. [34]

In the following years the Kiruna institute undertook contract research for the US Air Force according to a constantly growing program on ”HF- and VHF- Auroral zone propagation". The first quarterly report comprised the period 15 October, 1957 to 15 January, 1958 and reports were issued regularly until 1967, when the program ceased. By and large the Americans funded basic research, and they encouraged publication of results in peer reviewed journals. Nonetheless, they also secured, in Kiruna as on many other research sites in Europe, observations and data that were collected by their funded partners. The first equipment to be furnished by the Air Research and Development Command was delivered in Kiruna 13 January 1958.[35] In 1958 a new task was added to the program: to track satellites and provide data concerning time for closest approach, by telegraphic means, to the Space Group of AFCRC, during the first days after launching of a new satellite. Likewise the Swedish Institute was to provide the American military with Doppler data of every new Sputnik "for ten days to two weeks", and the scientists in Kiruna delivered.[36] The obvious reason for the Americans to be interested in the Kiruna institute was its geographical location, far north of the Arctic circle and in vicinity of Soviet territory. The close distance to northern Soviet Union also came in handy when the Americans wanted information on upper atmosphere effects of the nuclear weapon tests in Novaja Zemlja between September and November 1961 and Semipalatinsk in October 1962 (twice).[37]

The US military funds were crucial for the fledgling institute, which could probably do little but applaud the booster they received. In 1960 a full 55 percent of all funds at the institute came from the US Air Force, in 1959 and 1961 the contribution was at 40 percent and still in 1963 a third of the income came from the American military.[38] With increasing criticism of the United States in Swedish politics and media the Air Force program drew negative attention. Ultimately it was also questioned by the Swedish government and in 1967 it was terminated.

The Kiruna institute was also involved, albeit on a small scale, in the Kronogård launches, which again meant cooperation with the Americans, AFCRL as usual and also NASA this time, and with the Swedish Defence Research Agency, FOA.[39] Otherwise, the Swedish military seems to have paid little interest in the Institute's activities.[40] The explanation is probably that the kind of knowledge that space science could produce seemed of little interest to them. It was all the more useful for the Americans, who were increasingly interested in gathering of Arctic data, not only as a means of keeping track of Soviet activities but also in order to explore further oceans, climate, and meteorology in the Arctic, which in the US strategic planning assumed an increasingly important position as a potential theatre of war.[41] That the Swedish space research community was furnished with instruments and research funds should be seen in this context. Freedom of research was reasonably large, according to the general principles of US military post WWII research. To the extent that early Swedish space science was involved in any military innovation system it was American, rather than Swedish. For space research the Swedes were poorly equipped. From a policy perspective this is crucial. Military and security strings, and old networks across new NATO boundaries, needed to be cultivated if Sweden should stand a chance to move anywhere in space. At Kronogård they certainly came in handy.

The (slow) growth of a national space programme

During the three campaigns at Kronogård, scientific and technological know-how was built and maintained. However, the future of Swedish space activities was obscured by uncertainties concerning funding. On the international side, the discussions on a European Space programme continued during the years of the rocket campaigns. Sweden finally decided to join ESRO in 1962, but stayed out of ELDO, the European Launcher Development Organisation, partly because of neutrality considerations. The ESRO convention was ratified and operational in 1964. The same year Esrange, conveniently located some 25 kilometres from Kiruna and its Geophysical Institute, became one of ESRO's launching ranges and was inaugurated in 1966. However, to establish a permanent national organisation for space activities was not straight forward. Let us again step back a bit and look at that process.

In September 1963, the Space Committee appointed the year before to investigate the future of Swedish space activities published its official report which was distributed for consideration among parties concerned.[42] The Space Committee proposed the forming of a Space Institute and a special Space research council. Moreover, a special launching site next to that of ESRO was suggested. The motives for Swedish space activities were scientific, technical and industrial, and the hopes put on industry were high. The report argued that much of the technical know-how for telecommunication and data handling, as well as for power supply of heavy mechanical structures already existed within Swedish industry. Advanced propulsion systems and structures had been developed, partly as a result of military initiatives. Furthermore, the Swedish steel industry and research would be "extraordinarily well qualified" to solve material problems.[43]

To finance this and the membership in ESRO, an annual amount of 40 - 50 million SEK would be sufficient, which would correspond to the investment level of France and Great Britain, calculated in relation to GNP.[44] Considering the fact that all other Swedish research councils together received 46.2 million SEK in 1963/64, the negative response from the research community was perhaps not too surprising.

The general opinion from the round of considerations was that the space sector threatened to dwarf all other research areas, which were already under severe monetary strain. A number of instances argued that space activities were of importance and the amount asked for was a fair claim, as long as it did not mean a cut back in funding for other areas. Others favoured that space research should be forced to compete for grants in the same was as any research institution and not form a special program. The underlying worry was that a specific research council would short-cut the funding system. Among the few who wholeheartedly supported the proposal of the Space Committee was, understandably, the city of Kiruna which, contrary to everybody else, argued that the costs were not too high: "The economic contribution demanded to carry out the proposals of the Committee is […] in no way deterring. In relation to other countries, the costs are fairly modest. Doubts for economic reasons should therefore not be at hand."[45] Apparently the city of Kiruna realised early that localising space activities in the area could serve the region. However, this regional argument was not used either by the Space Committee or by the government at the time.

In conclusion, the round of considerations was negative and the proposal was buried.[46] The future of Swedish space activities was presented in the research bill in March 1964, the first of its kind.[47] The space initiative was rejected and activities should be coordinated through the research councils and the scientific and technological development should take place within the ESRO cooperation.[48] The Space Board of the Research Councils (Forskningsrådens rymdnämnd) was re-invented. In order to handle the Swedish contacts with the organisation the ESRO Committee was formed, creating two separate space bodies. [49] Swedish space proponents found themselves in the wilderness.[50]

A change of European organisation pawed the way for a "second birth" of Swedish space activities. In 1972, ESRO was, in short, reorganised and the European Space Agency, ESA, was founded. ESA would be engaged in both research and industrial development. Parts of the membership would be mandatory whereas parts would be voluntary. One aim for ESA was to develop research satellites, which meant that sounding rockets was not of the same interest any more. This in turn had effects for Esrange, which ESA wanted to discontinue. Here was an opportunity for Swedish space proponents to get the basis of a national sounding rocket programme, and taking over Esrange from ESA was used as an argument in the newly opened discussions on how to organise the space sector nationally.[51]

A Swedish Board for Space Activities (SBSA) and an executive branch in the shape of the state-owned enterprise Swedish Space Corporation (SSC) were created in 1972. Together with the national sounding rocket range at Esrange, Swedish space activities became, finally, firmly established. The cost for the year of 1972/73 was calculated to about 37.5 million SEK, a figure on which almost everyone had choked a few years earlier, but on the other hand the budget was largely funnelled through the department of industry and so did not compete with funding of universities and research councils.[52] The money came forth.

Space as an innovation system?

The history of the Swedish space program up to around 1980, briefly outlined above, can be reinterpreted as seen from the angle of innovation systems. Did there emerge a space innovation system in Sweden? The question is not as simple as it may seem.

From the very start both industrial and security arguments had been voiced as motives for Sweden to build a space program.[53] Space technology was considered a challenge of a magnitude that demanded cooperation between civilian engineering and military agencies. In early 1963 industry met with the military agencies to discuss the implications of Sweden's membership in ESRO. The conclusion was that if Sweden were to have any say in the development of rockets – after all, it was already late in the day with many rocket types already available in other countries – cooperation between military and industry was necessary. The FOA deemed it possible.[54] Monitoring from space, and an ability to be part of a satellite based communication network, would in any case be reason enough to stay abreast with developments.

However, the fate of the 1964 space research inquiry, halted industrial development as well. When the space sector finally reorganized it did so along a well trodden path. By around 1970 it was already an established fact that Swedish industrial innovation in several areas – railways, hydroelectric power, defence technology, nuclear power, telecommunications to mention some of the most important ones – had relied heavily on state technology procurement. Innovation systems were built with state funding and de facto industrial monopolies through state or private companies, the so called development pairs.[55] Technological competence came through universities and schools of technology who funnelled cohorts of trained scientists and engineers. Sheltered by long term state procurement the firms of the development pairs could build strong internal research departments which secured excellent competence flows between university- and firm R&D within these sectors of the economy. As a bonus, the innovation system created a solid platform for internationalization, and Sweden's leading multinationals of recent years are with few exceptions to be found among the winners in this state led procurement economy.

When the "second birth" of the Swedish space program was conceived in the 1970's it was this mind frame that guided politicians, civil servants, and industry. It was also evident that competing among all other fields of basic science in the research councils the Swedish space endeavour would have no future. Success must come through other inroads. Industry was one. When ESRANGE was established and in light of the super power space race in the 1960's the elite of Swedish procurement-funded firms turned increasingly optimistic about space technology investment and development. This optimism could not have been based on real life Swedish innovations in space technology, because so far there weren't any. It was based on expectations of space becoming a future global field of technology – and of the typical flow of taxpayer money to the R&D divisions of Swedish multinationals. Enthused by the political signals a group of Swedish multinationals, SAAB, ASEA, Ericsson plus, interestingly, including the Swedish Defence Telecommunications Agency, FRA, a military public agency, even got the idea that they would produce their own satellite. [56] This was indicative of the kind of mood that the procurement system of funding easily installed in the beneficiary firms. Besides, Swedish industrial firms had performed remarkable technological innovations before, in air craft technology, nuclear power, and telecommunications. Why not space? Curt Mileikowsky, then sales director and later head of ASEA (now ABB), and himself a PhD in nuclear physics, is reported to have said in 1965 that "space is the future" and it needed electric power – on space stations. "Today we build trains, in ten years we build space ships."[57]

True, the disappointing 1964 bill had overlooked the Space Technology Group, but after some deliberations a deal had been made between the ESRO Committee, the Space Board, and industry (ASEA, LM Ericsson and SAAB) guaranteeing 0.5 million SEK a year. Each part could lower its contribution in relation to contracts put on the Group. Organisationally, the Group was placed under the roof of TUAB (Teleutredningar AB).[58] This manoeuvre is of some interest since it points to the importance of keeping the technical know-how within the system, a system of which the limits were obviously blurred. In the 1950s and the 1960s, Sweden was short on technologically trained personnel. This was true in general, but proved a more severe threat to state enterprise and the defence sector, since they could not compete with industry by raising salaries as easily.

One way to counter this was for defence and industry to join forces and create the possibility of desirable employment. TUAB was such a company, formed in late 1958 by FOA and the Swedish electronics industry to undertake studies for the new surveillance system developed by the Swedish defence, STRIL 60.[59] SAAB was not originally part of TUAB, but became a member in the 1960s. Eventually also the Swedish weapons manufacturer Bofors joined in. The main task of TUAB was to serve the defence industry with investigations. Operations were utterly secret. The Space Technology Group was placed in the same building, but separate from the others, hence avoiding any security difficulties. The separation considered, seven years of co-localisation had an influence on the organisation and modus operandi of the Space Technology Group.[60] During the following years the industrial return for Swedish space industries involved in ESRO activities was meagre, and the national budget for space research small. The Space Technology Group carried out assignments for their funding bodies, but eventually the Space Board resigned in 1971, as a protest against the proposed budget for the following year.

This de facto marriage between industry and military was understandable given the heavy militarization of the Swedish high tech industries in the 1960s.[61] But it was also a sign of the path dependency of the actor network that had formed around space in Sweden, with military funded research institutions, and links to US military funding and technology. It was not yet clear where space would go. That was true anywhere and it was especially true in Sweden, where space in the 1960's had to survive in a limbo. With time, however, the military links, and the security arguments, faded into the background and civilian R&D and industrial arguments gained the upper hand, further underlined by the fact that the routine cooperation with the Americans had come under scrutiny. The industrial program took an increasing share of the total costs, partly as a necessary outcome of the principles for Swedish participation of the European Space cooperation.[62]

General procurement policies did not work out as easily in the space arena as they had in other areas of industry. The most salient difference was the size of the market. Although nuclear power plants and military aircraft were not that enormously numerous, they could at least rely on a fairly stable demand. Space research instruments were almost exclusively single commodity items, if they couldn't be turned into military or civilian applications, which, as it turned out, was rarely the case. Space technology did not therefore, at the end of the day, mature into an independent, large scale development pair in Sweden. After all, only a small number of Swedish firms became involved, notably SAAB, LM Ericsson and Volvo Aero.

So what did it become? Perhaps it could be termed an *auxiliary development pair*, contributing, with the support of state funds, to the success of Swedish industrial firms in other business areas. The procurement program was tacitly much more important than it may seem if only the marketed innovations are counted. It brought Swedish firms into contact with advanced technologies and provided networks with major European and American companies, such as Boeing that worked with SAAB. To be part of the international space consortia was popular among career seeking young engineers. Space related knowledge could be translated into mainstream areas of technology such as computers in aircraft, which became a major line of development in SAAB and Ericsson. Volvo engaged in an attempt to develop engines that could take ordinary airplanes into space orbits. The project failed, but the knowledge involved became part of the collective learning of the firm.[63] Something similar has been said about SAAB Space and its involvement in the Tele X-project during the 1980's, the difference of course being that this project was successful with a launch in 1989: "With Tele-X we moved ahead as a company."[64]

Towards the end of the 1970's the government finally made what turned out to be a major push for traditional procurement policies. However, perhaps somewhat ironically, it was not the initiative of the government but orchestrated by the SSC and perfectly timed to profit from a stale mate in the discussions on a new fighter airplane. Disturbances, particularly in SAAB, made the government prepared to propose an increase of "industrially motivated funding" at a level of a sensational three times the 1978 figure.[65] Again, the military connection is clear; if the Saab engineers could not produce airplanes they should be set to work on space technology. The new and higher level stayed and in the years to come the procurement policy continued unabated, despite the fact that its workings were rather of an indirect nature and implied huge industrial support. The program was repeatedly evaluated and the results were good enough to merit continuation.[66] However, the better part of the industrial support came as part and parcel of the European space cooperation which put limits to what the Swedish government could do. But the results at least demonstrated that industry used their ability to make something out of the ESA juste retour.

The regional turn

This remarkable development can perhaps best be interpreted as a late manifestation of the strength and path dependency of the Swedish post WWII-innovation policy paradigm. But times changed again, new hardships were around the corner, and the space sector had to look for new arguments to underpin its claims on state funding. In Kiruna, where focus was on basic science, interest in industrial applications and services came late. Some small early attempts at commercialization occurred, but the commercial potential was for the most part modest and not highly prioritized.[67] Kiruna had always been a company town, with one major, state owned mining company, and a solid state presence with heavy public infrastructure, an infantry regiment, and increasing state subsidies after a downturn in the mining industry in the 1970's.

This was the situation until around 1980, when there was a considerable shift on all levels. It started at the policy level where the industrial and science policies were now, as the structural crisis of the resource industries in the north aggravated, joined by regional development policy. It was evident that if Kiruna was to have a future it needed to complement the mine with other industries, and "knowledge" became a chief candidate. "From mine to mind," was the new motto.[68] Increasingly, applied research was now underscored in official documents about, and from, the Institute. An early attempt was in the field of infra acoustics in cooperation with the Work Life Protection Agency in Umeå in Västerbotten county which started from research on mechanical waves in the atmosphere. When regional development initiatives opened up the Institute grasped the opportunity and asked for new funds directed towards applied research. A small indication came 1979 in the budget proposal for 1980, and the following year a full bodied proposal was sent to the government which heeded the call. A key argument was that the absence of relevant high-tech companies in the counties of Västerbotten and Norrbotten made it necessary to locate development of the product after the research phase at the Institute's facilities, either in their lab near Umeå or in Kiruna.[69] The above mentioned government effort on space technology, which was conceived at the same time, consequently had a regional argument.

In the 1980's more applications of space related activities grew both in relation to IRF and Esrange and with explicit policy support from the state, which now acknowledged Kiruna as the Swedish space centre.[70] One example was the downloading of satellite images from the SPOT series in cooperation with Belgium and France under the company Satellitbild, founded in 1982, with regional and state support, as a subsidiary of Swedish Space Corporation.[71] SPOT provided much better images than the American Landsat and in combination with true map projection images the product range became at least partially successful, although high prizes prevented both the research community and developing countries from using the images. In 1999 Satellitbild fused with the remote image division at the SSC headquarters near Stockholm, and the Environmental Data Center, established a few years earlier as part of an initiative to locate an environmental institute in Kiruna. In recent years the market for satellite images from Kiruna, now within the state owned Metria, part of the National Land Survey of Sweden, has expanded thanks to Internet and Google Earth, but no dramatic growth phase has been reached. [72]

From the early 1990's Kiruna developed into a "space campus" with graduate training of space physicists and a space engineering program with some 80 students and a three year education in Geographical Information Systems, GIS. This increased substantially the number of "space workers" in Kiruna from 300 to 400, and it would soon reach 500, of which about two thirds were doing applied work or education. Kiruna also achieved an affiliation with the International Space Campus with their headquarters in Strasbourg, France. Again, the development was reinforced by official policy which seemed to have no intention of any traditional procurement driven innovation – the presence of industrial hi-tech firms in Kiruna remained too small for that – but instead focused on the regional dimension.[73] After all, people matter.

A multi-level innovation system

We have told a story of Swedish space activities from 1945 to the present, from the fragile hopes of ionospheric physics in the Swedish north to a billion dollar industry with a de facto space centre in Kiruna with some 500 people working on a daily basis as scientists, engineers, administrators, university professors, or students. What can this story tell us of Swedish innovation systems? At the face of it, it may seem a far fetched idea to call this an innovation system. The difference between space and power plants for example was that there was virtually no market outside the specialized space research, in particular since neutrality policy put a cap on what kind of technologies the Swedish defence sector could invest in.

We have suggested above that the Swedish space experience could be described as an *auxiliary development pair*, since it assisted through high-tech subsidies and international industrial cooperation the "core" development pairs in aircraft, computers, telecommunications, engines, and weapons. On the other hand this description is limited to industrial innovation, whereas in reality the space endeavour has widened its base. Perhaps a better way of describing Sweden's space activities is to regard it as a "post-development pair technological system," adapted to multi-policy aims.

When, after a long period of uncertainty, the government took on the role of funding agent for a Swedish space technology its role model was first the development pair. Yet, investment in space activities, due to the peculiarities of the market, had to adopt a mode of radical flexibility. Each company worked on technologies that they mastered and could develop further; innovation deriving from space activities could always be used in ordinary lines of product development and R&D. This was a wise strategy. The Swedish space industry eventually managed to compete internationally on subsystems, but not more.

For the innovation system it meant adapting to working on different spatial scales at the same time and constantly playing on heterogeneous investment schemes. Activities on the international, national and regional level was pared with active relationships with a range of policy areas. First it was industrial policy, dealing with the different industrial branches mentioned above, plus potential emerging sectors of the economy in e.g. computer science or instrument technology. Then it was science policy; the space activities budget was presented as part of the general science budget, with tri-annual long term budgets starting in 1982. Security and defence policy, possibly also foreign policy, was of diminishing importance since the end of the 1960's but given the fact that so much technological competence was assembled within the military sector it could not be altogether avoided, nor could implications of the fate of the rich military and Air Force facilities in the far north of Sweden. Internationalization was a strong argument for scientific cooperation, aiming towards higher national quality. With time, international cooperation argument became almost imperative as it turned out to be impossible to withdraw from major common undertakings.

Regional policies became increasingly important as the structural renewal of the Kiruna area became a priority, with significant effects on the budget allocations of several government offices from the late 1970's onwards. For the same reason, although somewhat later, education policies became crucial, and as the concept of environment expanded to cover various dimensions of sustainability and was used to legitimate public investment in the 1990's there was yet another policy area that the Swedish space sector needed to relate to. This had a marked effect in Kiruna, where an Environmental Institute was located in the 1990's in cooperation with the two northern universities of Umeå and Luleå.

The Swedish space sector has built its strategy from a position of weakness, which it has exploited successfully through flexible adaptation to different policy regimes and policy goals, which in turn have changed according to global trends and conditions. As an innovation system it became subordinate, but perhaps more significantly it emerged as a social-scientific innovation system through its role in the transformation of Kiruna. The multi-level, multi-policy strategy has taken on a city and a region as an innovation goal. On a small scale, space activities have transformed Kiruna into a *science region*.[74] Usually, science regions are built around major universities, research institutes and industrial research parks; the quintessential model is California's Silicon Valley. In the last several decades, however, many smaller versions have appeared around the world to shape one of the major structural and urban phenomena of our age. As knowledge society moves forward and science and technology occupy larger portions of society, the kind of social-scientific innovation system that space activities in Kiruna represent is likely to grow in importance.

This leaves us with a kind of happy paradox. While space science never took off into an independent innovation system, it did something much more innovative as it acted as a driving force in a prototypical process of change that has helped shape the contours of a northern science region. Over a fifty year period the Swedish space sector has made a transition from the military innovation system, where it was about to enter in its early years, to a social and regional science based innovation system.

We have turned 180 degrees. The first space science effort in Sweden was one that demanded empty space – and even required the redistribution of local people in the small villages of Nausta. Although unique, it was cousin and kin with contemporary Cold war space and military science activities in Nevada and Woomera – sites where secret technologies were being tested, far away from public scrutiny and tightly interwoven with secret institutions and public agencies. To survive, and to flourish as a state funded policy arena, space science has had to do quite the opposite: help stimulate domestic industry and populate the vast Swedish North. In an interesting way it is the involvement in innovation systems – industrial and regional – that has secured the long term viability of the science, not the other way around. It is also when space science has been developed for people, not in the absence of people, that it has been successful. Swedish space science has moved, in a very literal sense, from warfare to welfare.

The ultimate question is, however, what people? Perhaps we should not forget that the first welfare idea when Esrange was planned was to calculate the prize of the reindeer that might get killed by a rocket from space. The owners of the reindeer were the Saami. The Swedish space centre used to be privileged herding lands. In the ongoing marginalization of the indigenous economy and culture space activities have played a role that remains to be investigated. Still, we can safely say that the issue involves much more than the prize of a reindeer. The scientists were of course right in their calculations: the risk was near zero and no reindeer was ever killed from a Lapland rocket, so far. The casualties have been of a different kind. Innovation systems are not innocent.

[1] ”FOA och kärnvapen: dokumentation från seminarium 16 november 1993”, FOA VET om försvarsforskning, 8. FOAs kärnvapenforskning (FOA Veteranförening med stöd av FOA, 1995); Wilhelm Agrell, *Svenska förintelsevapen: Utvecklingen av kemiska och nukleära stridsmedel 1928-1970* (Falun, 2002).
[2] Jan Stiernstedt, *Sweden in Space: Swedish Space Activities 1959-1972* (Noordwijk, 2001), 71 ff.
[3] Cf Georg Witt interview 12 August, 2005.
[4] ”Första svenska rymdskottet upp från ramp i Lappland”, *Dagens Nyheter*, 10 August, 1961. Note that the result of the campaign was of less interest; the article was published four days before the shot.
[5] During the following years the campaigners realised the value of public-relations and worked on producing material for the media. Pressmeddelande från MISU, ”Information beträffande svensk-amerikanskt raketprojekt sommaren 1962”, Kronogård archive, SSC.
[6] Stiernstedt, 13 ff. In Swedish the committee was named Forskningsrådens kommitté för rymdforskning, later Svenska kommittén för rymdforskning. Bengt Hultqvist, *Space, Science and Me: Swedish Space Research during the Post-war Period* (Noordwijk, 2003), ch. 1.
[7] Stiernstedt, 17 ff. The forming of ESRO and ELDO and its successor ESA has been thoroughly dealt with in John Krige et al, *The History of the European Space Agency 1958-1987,* Vol I & II (Noordwijk, 2000).
[8] For example Bert Bolin and his colleagues at the Department of Meteorology at Stockholm University (MISU), had suggested the study of noctilucent clouds at an altitude of about 80 km, where there could be no normal clouds. Bengt Hultqvist wanted to explore the “polar cap absorption” which had been detected a few years earlier. Solar-eruption was followed by radio-wave absorption and aurora borealis, and the effects on radio communication in the polar region were of interest. Stiernstedt, 73.
[9] Stiernstedt, 15.
[10] Stiernstedt, 74-75. The military connection here is interesting. During the 1950s, Sweden had failed to develop its own missile system, and instead negotiations with the US had been carried out. In early 1959, Sweden and the US signed a contract on 2000 Sidewinder air-to-air missiles. In January 1961, Sweden and the US signed a General Security Agreement, and in March Sweden was allowed to purchase also air-to-air missile Falcon and surface-to-air missile Hawk. Hence, the technology was released to Sweden, even though she was not a member of NATO. Mikael Nilsson, *Tools of Hegemony: Sweden, the United States, and Military Technology during the Cold War, 1945-1962* (Stockholm); Cf Thomas Jonter, ”Det amerikanska spåret: En undersökning av IB:s bildande och eventuella kopplingar till USA”, SOU 2002:95, 172 ff.
[11] ”Riskzonsberäkning”, MISU, juli 1961; ”Yttrande över riskzonsberäkning” FOA2, Dnr 2965-240.
[12] Stiernstedt, 109 ff; ”Ekonomisk sammanfattning av expedition Kronogård”, MISU, 3/10 1962, Bert Bolin.
[13] Johan Martin-Löf personal communication 10 November, 2006.
[14] Nina Wormbs, *Vem älskade Tele-X? Konflikter om satelliter i Norden 1974-1989* [Who loved Tele-X? Conflict on Satellite in the Nordic Countries 1974-1989] (Hedemora, 2003).
[15] Ginger Bromfalk, unpublished term paper on the history of Nausta village (2006), p. 15; copy with the authors. The comparative advantage of geography has been emphasized again in a government inquiry into the possibilities of international materials and weapons testing in the same region, SOU 2004:77 *Snö, mörker och kyla* [Snow, Darkness, and Cold]. For testing speaks, p. 13, that it will take place in “the northern part of Sweden where the combination of large, scarcely populated areas, the climate and existing military infrastructure creates partly unique conditions for military testing and training. Cost-efficient development is considerably facilitated by the existing military training facilities and infrastructure in the area”.
[16] Sverker Sörlin, *Land of the Future: Norrland and the North in Sweden and European Consciousness*, Center for Arctic Cultural Research, Umeå University, Miscellaneous Publications 8 (Umeå, 1989).
[17] Peter Morton, *Fire Across the Desert: Woomera and the Anglo-Australian Joint Project 1946-1980* (Canberra, 1989).
[18] Maths Isacson, *Industrisamhället Sverige: Arbete, ideal och kulturarv* (Lund, 2007).
[19] Paul R. Josephson, *Industrialized Nature; Brute Force Technology and the Transformation of the Natural World* (Washington, 2002).
[20] Stiernstedt, 80.
[21] Morton, ch. 5.
[22] Generally on the US development, Kristine Harper, *Boundaries of Research: Civilian Leadership, Military Funding, and the International Network Surrounding the Development of Numerical Weather Prediction in the United States*, unpublished diss. Oregon State University, 2003.
[23] General on fallout issues, Philip L. Fradkin, *Fallout: An American Nuclear Tragedy* (1989), new ed. (Boulder, CO, 2004). See also A. Costandina Titus, *Bombs in the Backyard: Atomic Testing and American Politics* (1986), second revised edition (Reno & Las Vegas, NV, 2001), in particular ch. 4.
[24] Bert Bolin, “Carl-Gustaf Rossby: The Stockholm Years, 1947-57”, *Tellus A* **51** (1), pp. 4-12. The initiative to bring Rossby to Sweden seems to have come at least partly from glaciologist Hans Ahlmann, who received

support from the military. Memorandum 4 April 1946 by chief of Sweden's Air Force, B. G. Nordenskiöld, War Archives, Stockholm, FS/V 19(44).

[25] Ronald E. Doel & Allan A. Needell, "Science, Scientists, and the CIA: Balancing International Ideals, National Needs, and Professional Opportunities", in *Eternal Vigilance?: 50 Years of the CIA*, eds. Rhodri Jeffreys-Jones & Christopher Andrew (London & Portland, 1997), 70-71.

[26] The paragraph and the following build on Harper, 299-300.

[27] Bert Bolin interview, 2 June, 2005; Harper 2003; Sörlin; "Narratives," includes evidence of MISU funding from the Swedish Air Force as well as from the US Air Force and from the Office of Naval Research.

[28] Per Lundin (ed.), *Att arbeta med 1950-talets matematikmaskiner* [Working with the 1950's Mathematics Machines], Transcript from a witness seminar on early Swedish computing history, Museum of Technology, Stockholm, 12 September 2005, 21-23. In his statement at the witness seminar Bolin underscores the close cooperation with the Swedish Air Force, which provided funding and, perhaps more importantly, provided necessary weather maps and staff for the drawing of maps and for tests of the computer based models in regular prognostication activities. This statement is also corroborated by numerous documents in the War Archives (Stockholm), for example a document of 1 March 1956 regarding "running of BESK [acronym for the Swedish computer] during military training operation", ref. 25(578:5). See also Germund Dahlquist, "Väderleksberäkningar på BESK" [Weather computations on BESK], *Teknisk tidskrift* 1955.

[29] Jonter.

[30] Thompson to Chief, Atmospheric Analysis Laboratory, ca. November 1953 (Thompson papers, Correspondence 1953-1954). Harper, 420.

[31] "Plan for coordination of military meteorological service" was one of five, out of a total of twelve, points in a memo from the Head of Defence Operations [Försvarsstabschefen] that were approved by the Swedish government and were also followed up by operational contacts in the following years. Memo 3 September 1949 and details of coordination quoted by the Neutrality commission, SOU 1949:11, ch. 6, and by Magnus Petersson, *'Brödrafolkens väl': Svenska säkerhetspolitiska relationer 1949-1969* ['The Good of our Brethren': Swedish Security Policy Relations 1949-1969] (Stockholm: Santérus, 2003), 234-35. However, the politics of the weather-computing revolution were not easy, and the Stockholm school could not in any way be equated with the political agenda on the American side, nor, in particular, the one represented by von Neumann, who was a zealous anticommunist. Rossby seems rather to have educated an internationalism that went far beyond the demarcation lines of the cold war, a spirit that was to be continued in the department. Anders Persson, "Early Operational Numerical Weather Prediction Outside the USA: An historical Introduction: Part 1: Internationalism and engineering NWP in Sweden, 1952–69", *Meteorological Applications* 12 (2005).

[32] These also comprised the Abisko research station, founded in 1906, the Tarfala station for glaciological research, founded in 1945, and a small observatory on the Pårte mountain in the alpine Sarek area.

[33] Bengt Hultqvist interview, 13 March 2007. Ingrid Sandahl, "Rymden" [Space], in *Kunskapsarena Norrland* [Knowledge Arena Norrland] (Umeå, 2007).

[34] Bengt Hultqvist, "Reserapport rörande studiebesök i U.S.A.", [Report from a study tour in the U.S.], Report to the Board of the Royal Swedish Academy of Sciences Resarch Stations in northern Norrland, 7 December 1956. Mimeo, IFR Archives, Kiruna.

[35] "Studies on HF- and VHF- Auroral zone propagation: Quarterly technical status report no. 1, 15 October 1957-15 January 1958", by By Bengt Hultqvist, Contractor & Johannes Ortner PI. Contract No. AF 61(514)-1314. IFR Archives.

[36] Quarterly report 5, January 1959, p. 8.

[37] Terence Elkins & Alv Egeland, *Ionospheric Effects Associated with Nuclear Weapon Tests July-December 1962. Scientific Report KGO 63 2, 1 March 1963*. B. Hultqvist et al, *Report on Observations made at Kiruna Geophysical observatory during the Series of Nuclear Weapon tests Carried out at Novaja Zemlja between 10 Sept. and 4 Nov. 1961*. Scientific Report KGO 611, 11 December 1961.

[38] Swedish Institute for Space Physics, Report to the Space Commission [Synpunkter på rymdutredningen], memo, 4 January, 1995, table 6. Swedish Institute for Space Physics Archives.

[39] Bengt Hultqvist was responsible for measurements in cooperation with Dr Ludwig Katz at the AFCRL's Geophysics Research Directorate. Sven Grahn, Kronogård dossier, September 2006.

[40] Bengt Hultqvist interview, 13 March, 2007.

[41] Ronald E. Doel, "Polar Melting When Cold War Was Hot", *San Francisco Examiner*, 3 October, 2000; A15. Ronald E. Doel, "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA after 1945", *Social Studies of Science* 33(October 2003), pp. 635-666. Fae Korsmo, "The Military and Arctic Research, 1945-1950", paper presented at History of Polar Oceanography, Barrow, Alaska, September 2004. Fae Korsmo, "NSF/Tokyo Report: Science in the Cold War: the Legacy of the International Geophysical Year", 23 April 1998, National Science Foundation, Washington DC, http://www.nsf.gov/pubs/1998/int9814/int9814.txt (accessed 11 March, 2007).

[42] Government bill 1962:85; Organisatoriska åtgärder för rymdverksamhetens främjande, SOU 1963:61.
[43] SOU 1963:61, 42-44.
[44] SOU 1963:61.
[45] Kiruna Stad, remissvar på SOU 1963:61. Eck dep., Reg. Beslut 6/3 1964, Nr 79 (Government bill 1964:69). The county council of Norrbotten also regarded the city of Kiruna a suitable place for a space institute, considering the plans for a future technical university in the city of Luleå. Länsstyrelsen i Norrbottens Län, remissvar på SOU 1963:61. Eck dep., Reg. Beslut 6/3 1964, Nr 79 (Government bill 1964:69).
[46] Stiernstedt argues that perhaps also a few changes on the administrative level in the Ministry of Education contributed to the outcome of the procedure, 132-133.
[47] Stiernstedt, 133.
[48] Government bill 1964:69, p 58-60, 64; Stiernstedt, 139-141.
[49] Stiernstedt, 139 ff. Money was channelled through NFR, TFR, FOA and industry and reached 3 million SEK in the budgetary year of 1963/64. This was 1 million SEK more than the previous year. Added to that was 3.7 million for ESRO membership and programmes.
[50] The term Wilderness Years has been used by both Stiernstedt (165) and Hultqvist (65).
[51] Stiernstedt, chs 19 & 20.
[52] Government bill 1972:48, 37.
[53] Government bill 1964:69, 36, 46, 49. Government bill 1972:48.
[54] SOU 1963:61, p. 115.
[55] Cf Mats Fridlund, *Den gemensamma utvecklingen: staten, storföretaget och samarbetet kring den svenska elkrafttekniken* (Stockholm, 1999).
[56] Per Nobinder interview 19 February, 2007. Nobinder who had a military background was responsible for the industrial liaison committee in Rymdbolaget from the early 1970's up to 2000.
[57] Lennart Lübeck interview 14 December, 2006. Mileikowsky's enthusiasm for space is corroborated by Otto von Krusenstjerna, a chemist, who headed ASEA's research laboratory in Västerås and was sent by Mileikowsky on a mission to Cape Canaveral in 1969. Interview 25 April, 2007.
[58] Stiernstedt, 143.
[59] Ingemar Dörfer, *System 37 Viggen: Arms, Technology and the Domestication of Glory* (Oslo, 1973), 102-103.
[60] Lennart Lübeck personal communication 7 February, 2007.
[61] Cf David Edgerton, *Warfare state: Britain, 1920-1970* (Cambridge, UK, 2006).
[62] The funding mechanism was explained in Government bill 1962:85.
[63] Per Nobinder interview 19 February, 2007.
[64] Phone interview SAAB Space CEO Peter Möller 9 January, 2007; Nina Wormbs & Gustav Källstrand, *A short history of Swedish space activities*, ESA report (Noordwijk, 2007).
[65] Government bill 1978/79:142, quote on 1, Wormbs 1997, chapter "Rymdlyftet".
[66] Per Nobinder interview 19 February, 2007; Wormbs & Källstrand 2007, ch "Investigations of the space system".
[67] Bengt Hultqvist interview 13 March, 2007.
[68] Sörlin, *Land of the Future*, 259.
[69] Special funding for applied research, certain years from Department of industry, continued throughout the 1980's but was later made part of the basic funding of the Institute which grew drastically in the early 1990's, 100 percent from 1987 to 1993. IRF budget proposal 1980/81, dated 6 August 1979. Bengt Hultqvist, "Proposal for test activities towards development of new products at the Kiruna Geophysical Institute during a three year-period", 30 May 1980. Government bill 1982/83:120, 7-8. "Funds for applied reseach and product development". Department of Industry 22 May 1986. Government bill 1986/87:80, pp. 141-42. Government bill 1987/88:86, pp. 29-30. Swedish Institute for Space Physics, Report to the Space Commission [Synpunkter på rymdutredningen], memo, 4 January 1995, table 7. All non-printed documents in the Swedish Institute for Space Physics Archives, Kiruna.
[70] Government bill 1985/86:127, 7-8. "From the viewpoint of regional policy the Swedish space activity has a particular significance for the northernmost parts of the country."
[71] Claes-Göran Borg interview, 10 May, 2007; SSC Annual Report 1982, 1.
[72] Sandahl.
[73] See e.g. SOU 1995:78 *Den svenska rymdverksamheten* [The Swedish Space Program].
[74] Robert Kargon et al, "Far Beyond Big Science; Science Regions and the Organization of Research and Development", in *Big Science: The Growth of Large-Scale Research,* eds. Peter Galison & Bruce Hevly (Stanford, 1992), 334-354.