NATO, Air Defence and Science: Staying up-to-date

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NS-310B: Bachelor's Thesis

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29 July 2014

Abstract. Quite early on in its existence NATO has been involved in the pursuit of science and R&D. Two prime examples of this which will be examined in this study are the SHAPE Air Defence Technical Centre (SADTC) and the NATO Science Committee. SADTC was established in 1954 to assist NATO's European Command in the R&D aspects of realizing an effective Air Defence and Early Warning system for the Western part of continent; most of its activities focused on the very practical aspects of defence system implementation and determining the technical merits of competing systems and proposals as an impartial actor. The Science Committee was founded in the aftermath of the launch of Sputnik and sought to strengthen the quality, quantity and sense of community of scientists within the Atlantic Community. As its terms of reference were too far from the Alliance's core business its main contribution appears to have been in the realm of public diplomacy rather than science. In this thesis it is argued, that operational needs of the alliance shaped their creation and programmes of work which focused on engineering and implementation rather than actual system development which was beholden to national industries. Their aim was to facilitate keeping up-to-date with Soviet air activity and on the frontline of scientific progress.

Contents

1. Introduction

This thesis intends to study and consider the scientific efforts undertaken within the North Atlantic Treaty Organization (NATO) and its Supreme Headquarters Allied Powers Europe (SHAPE) prior to establishment, concentrating on the years from 1949 to 1960, with a particular focus on the work done in the SHAPE Air Defence Technical Centre (SADTC), and the NATO Science Committee (NSC). In so doing, our two central questions will be: "What scientific efforts were conducted within NATO and SHAPE?" and "What role did the Netherlands play in promoting and conducting the scientific and research agendas of these institutions?" Our two case-studies (SADTC & NSC) are well-suited to considering both questions, as they regard two very different instances of NATO activity in science policy, whilst both featuring clear Dutch involvement.

In doing so, we shall consider both technical and political aspects of the challenges faced by the Western allies during the early Cold War, and this entails examining the interaction between scientific idealism and internationalism on one hand, and political realism inspired by protection of national interests on the other.

Following this introductory chapter will be a chapter sketching a broad outline of the historical context relevant to NATO science during the early Cold War. Chapters 3 to 5 take a detailed look at the SHAPE Air Defence Technical Centre (SADTC). Chapter 6 explores the creation and work of the NATO Science Committee (NSC), and chapter 7 proceeds to briefly survey the background and work of a number of other research organizations set up under NATO auspices during the period under consideration. Chapter 8 deals with the role played by the Netherlands within NATO's scientific initiatives, placing this within the broader outlook of North Atlantic power relations and the consensual construction of US hegemony. Having addressed the first question of what science is conducted in chapters 4 to 7, and the second question of the Dutch role in chapter 8, the final chapter is devoted to summarizing the conclusions to be drawn from this thesis.

Chapter-by-chapter Overview

To understand the driving force behind NATO's scientific endeavours, it is important to appreciate the historical context that provided the underlying motivations. What moved an alliance inspired primarily by political and military requirements for collective defence to not only conduct research, but furthermore to establish permanent research institutions, and even to promote basic science? *Chapter 2* will show how the initiatives to create both the SADTC and the NSC derived their impetus from developments in the Cold War.

Having a broad strategic outlook, we zoom in to the more specific tactical threats faced by NATO in Europe during the early fifties. *Chapter 3* will study the emergence of air defence as SHAPE's chief tactical problem, how this led to the SADTC's initial temporary establishment, and its later transformation to a permanent internationally financed organization.

Answering the threat facing SHAPE was found to be technically so complex that an ad hoc study group concluded that it could not comprehensively render advice on the necessary measures to address it, outlining the *raison d'être* for the SADTC. *Chapter 4* discusses the technical aspect of the challenges faced by the SADTC in realizing effective air defence and early warning, and considers their technological solutions.

Armed with a basic understanding of the problems confronting SHAPE, we can compare this to information on SADTC programmes of work and secondary accounts to interpret what role it fulfilled. *Chapter 5* will give a broad overview of the actual work undertaken by the SADTC, connecting it to the problems and solutions outlined in chapter 4.

3 years after the initiation of the SADTC, the NATO Science Committee was established against a very different background and offers an alternative perspective on NATO's interest and involvement in science. *Chapter 6* looks at the origins and activities of this NATO institution.

After the detailed consideration of two different instances of institutionalized NATO efforts in the realm of science and R&D, we set up our broader evaluation of the political side of science within NATO. We do this by briefly enumerating and qualifying other relevant examples (such as the Advisory Group for Aeronautical Research and Development (AGARD)) whose in-depth appraisal was beyond the scope of this thesis. *Chapter 7* regards a general survey of other organizations with a focus on research that were set up under the flag of NATO during the fifties.

The second question this thesis deals with concerns the role played by the Netherlands in shaping the alliance's agenda. Our case-studies are well-suited to this, as the Dutch government was directly involved in the establishment of the SADTC, and Dutch representation was present (but much less visible) in the NSC from its first meeting onward. An interesting avenue that will be briefly explored is that in both, a central role was played by professor G.J. Sizoo who was SADTC president and Dutch NSC representative. Furthermore, as the Netherlands is an instance of both a smaller and a European country within the alliance, this will offer us an interesting perspective on the concept of US post-war empire-building by consensus. *Chapter 8* considers the extent and nature of Dutch and European influence in determining the role and direction of science within North Atlantic bodies.

Finally, *Chapter 9* summarizes the observations and insights collected in chapters 2 to 8 in order to draw conclusions regarding what scientific efforts were conducted within NATO and SHAPE and what role the Netherlands played in them.

2. Historical Context

In this chapter we seek to establish the driving forces behind NATO's initiatives in the field of science and research. The actual requirements and deficiencies which NATO institutions such as the SHAPE Air Defence Technical Centre (SADTC) and the NATO Science Committee (NSC) addressed were not new. They arguably existed with no less magnitude prior to the ratification of the Washington Treaty itself than they did in the 1950s. Nevertheless, it took several years for the concrete steps leading to the establishment of the SADTC (1954) and the NSC (1957) aimed at tackling these problems.

This initial inertia may be attributed in part to the many other pressing matters at hand in NATO's formative years. William Nierenberg argues that NATO action on scientific matters has actually been relatively swift[1] if one considers the O had not yet been put into NATO in 1949. However to an important degree, as emphasized by John Krige[2], external developments in the Cold War were crucial. Thus, to understand the delay in perceiving a sense of urgency and assigning priority to these challenges, an appreciation of the broader NATO context against which these developments took place is required.

[1] Nierenberg 2001, 365
[2] Krige 2000, 88-89

This chapter contains two parts. First, a look at how the heating up of the Cold War led to growing emphasis on operationally practicable battle plans as opposed to a more theoretical deterrence by purely political alliance. Second, we consider the shift from direct military confrontation to competitive co-existence featuring a more comprehensive standoff, including in the realm of scientific sophistication. Thus the first section gives the historical context for forming the SADTC, whilst the second section does the same for the NSC.

2.1 The Need for Integrated Air Defence

In this first section we shall argue that the context conducive to the SADTC's establishment was formed by the growing perception of a clear and present Communist military threat. We briefly discuss how and why the North Atlantic Treaty Alliance turned from a political into an operational organization, and the establishment of SHAPE whose demands were to eventually father SADTC.

When the North Atlantic Treaty entered into force on 24 August 1949 (it was signed on 4 April 1949), the O had not yet been put into NATO; that is to say, the North Atlantic Alliance did not immediately entail an operational institution with the means and authority to centrally coordinate the effectuation of the concrete air defence of the European continent. It took some time for the alliance to grow into this, in part because there were still a lot of precedents to be set, policies to be designed and implemented, and other matters to be discussed. But most of all, the external conditions were initially not yet conducive to producing the political will to realize this. In the historically sensitive area of air defence, many European allies, most importantly France and the UK[3], were quite reluctant to compromise sovereignty and consequently insisted adamantly on maintaining it as a 'national responsibility'.

From political to operational alliance

The precise mission and raison d'être of NATO have always been subject to some controversy, in spite of Lord Ismay's famous summary "to keep the Russians out, the Americans in, and the Germans down". This is not so presently[4], nor was it so at its

[3] Collier 1957, 1-20

[4] Contemporary opinions and priorities remain divided between emphasis on the operational out-of-area interventions aspect favoured by most older (Western) members whilst the more recent (Eastern) additions to the alliance favour a focus on the traditional aspect of providing collective defence.

inception. To see this, just consider the non-specific phrasing in Article Five of the Washington Treaty[5] vis-à-vis the clear commitment to military action in Article IV of its progenitor, the Brussels Treaty[6]. During NATO's formative period, the question asked was whether the alliance was from a practical point of view restricted to merely the guarantee of collective defence, thereby essentially entailing a Western European subscription to a US nuclear umbrella insurance policy, or if it should go further than that and actually work to tangibly plan and arrange for such collective defence and realize an integrated military structure.

During the earliest years after the defeat of Germany, even after the Berlin blockade signalled the rising West-East tensions, the Soviet threat had been viewed as primarily political in nature[7]. The policy emphasis in the aftermath of the Second World War had been chiefly on effectuating the political and economic reconstruction of Europe, somewhat to the neglect of rearmament and defence spending. This had obvious domestic reasons, but as the conflict was primarily seen in political and economic terms this course of action could actually be argued to answer the perceived ideological challenge posed by the USSR.

The first Soviet nuclear bomb in 1949 and moreover the Korean War from 1950 to 1953 however, dramatically changed this outlook on both sides of the Atlantic. Suddenly the threat of military aggression from the East, not necessarily originating from just one single state, became a lot more tangible. The heightened anxiety on the part of the Western allies led to a more cohesive alliance, and an accompanying dramatic rise in willingness to pool military resources and sovereignty, in order to contribute to collective defence; the political and game theoretical dynamics behind this change in behaviour is elegantly explained by Stephen M. Walt's 'threat-balancing' reformulation[8] of Kenneth Waltz's Defensive Realism[9].

The re-orientation towards more focus on effective operational defence materialized not only in sharply rising defence budgets, but also in calls for "an integrated force under centralized

[5] Article 5 of the North Atlantic Treaty (signed in Washington on 4 April 1949) states that Parties to the treaty will in the case an armed on attack on one of them “assist the Party or Parties so attacked by taking forthwith, individually and in concert with the other Parties, such action as it deems necessary”.

[6] Article 4 of the Treaty of Economic, Social and Cultural Collaboration and Collective Self-Defence (signed in Brussels on 17 March 1948) contains the much stronger statement that Parties to the treaty will in the case of such an armed attack “afford the Party so attacked all the military and other aid and assistance in their power.”

[7] Osgood 1975

[8] Walt 1987, 17-33

[9] Waltz 1979, 111-114

command which shall be adequate to deter aggression and to ensure the defense of Western Europe"[10], i.e. the Supreme Headquarters Allied Powers Europe (SHAPE)[11]. This force was to be placed under a Supreme Allied Commander Europe (SACEUR) "...who will have sufficient delegated authority to ensure that national units allocated to his command are organized and trained into an effective integrated force in time of peace as well as in the event of war"[12]. General Dwight D. Eisenhower, commander of Operation Overlord during WWII was to become SHAPE's first SACEUR and during his survey tour of European NATO capitals[13] he further consolidated the already nascent European commitment to drastically augment national defence budgets. This placed the Alliance on the road towards tackling far-reaching operational problems, both in terms of international political will as in terms of material means as emphasis was partially shifted from reconstruction to rearmament of Western Europe.

Air defence in the spotlight

Still, air defence had not received top priority, as there had been more of a focus on meeting deficiencies and achieving overall interoperability and effective command structures. The United States, whilst it had been involved in developing a continental Early Warning system for North America had to the mind of UK officials apparently "never [...] been particularly interested in the technical problems of air defence"[14]. France for its part, actually had its air territory divided into two zones, only one of which fell under NATO jurisdiction; all to maximize sovereignty retained.

The atomic factor in modern war, entailed that the initial strike would be nuclear and crucial: Soviet successes in the development of thermonuclear weapons had changed strategic reality. It took some years before the consequences had permeated all levels of strategic planning at NATO however. Advent of first Soviet jet bombers, drove the point home however. They were more or less impervious to regular ground-based anti-air defences and the USSR possessed tactical air superiority, posing NATO Europe with a serious challenge.

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[10] NATO, Final Communique at Fifth Session. 26 September 1950.
[11] Selected Entries from SHAPE Archives available in the NATO Archives (afterwards SHAPE), Origin and Development of SHAPE 1953, 18-19
[12] Ismay 1954, 185
[13] SHAPE, Origin and Development of SHAPE 1953, 25-61
[14] UK National Archives (afterwards UK Archives), J.E. Lucas – Note for the record. 13 January 1955. T/225/2478, D.P.388/01.

For more detail, please refer to Chapter 3, which expounds on the tactical necessity for improved air defence and early warning.

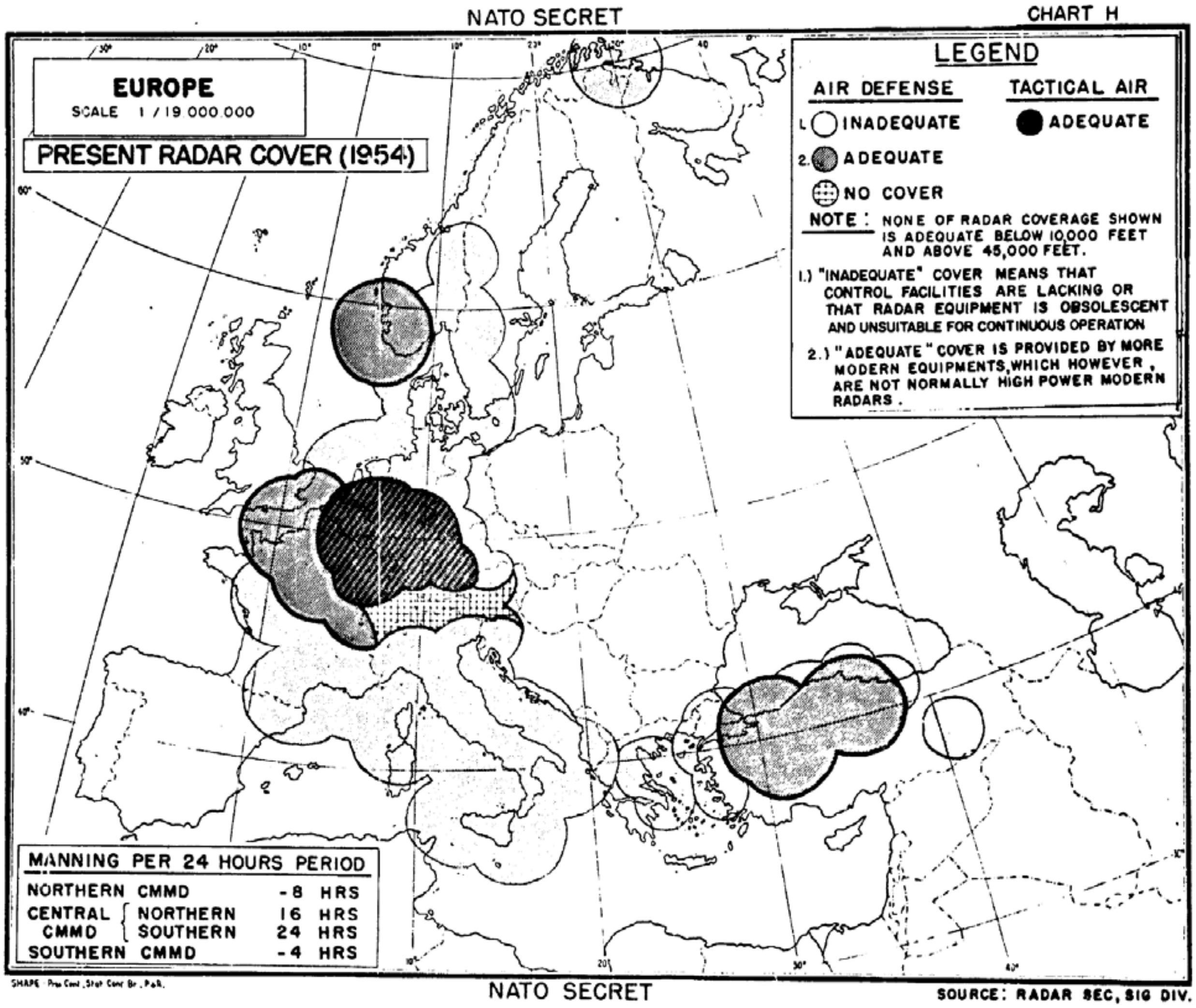

Figure 1: NATO Radar Cover in 1954. Source: SHAPE/626/54 (AG 1250 CS)

In summary: between 4 April 1949 and 2 December 1954 the situation had changed to the extent that General Gruenther, NATO's Supreme Allied Commander in Europe (SACEUR) could move towards proposing acceptance by NATO's Military Committee's Standing Group that "...development of an acceptable air defense capability for Continental Europe requires [...] a system of unified command responsibility under SACEUR"[15]. This included

[15] NATO Archives, Brussels (afterwards NATO), *The Military Progress of the North Atlantic Treaty Organization – Report no. 7*. 2 December 1954. M.C. 5/9, paragraph 20.

as a direly needed (see figure 1) centrepiece, effective and complete radar cover of Europe for early warning.

As the 50s progressed however, whilst air defence continued to feature relatively prominently as a topic of concern within the alliance's Military Committee, NATO's immediate concern for an all-out massive attack abated. The Atlantic community's attention was in part diverted away from the direct military aspect of force requirements to focus again on more strategic concerns; this focus was to now settle on the struggle for technological and scientific superiority. This is the subject of the next section.

2.2 Changing Nature of the Threat: Competitive co-existence

In this second section, we consider the historical background against which the emergence of the NATO Science Committee must be understood; that was a growing and grave concern that Soviet scientific prowess might in near future outstrip the West. The crucial watershed in developments leading up to its establishment is the launch of the Soviet Union’s artificial satellite: Sputnik. However, before we consider this toward the end of the chapter, we consider chronologically a number of minor ‘shocks’ to Western self-confidence in terms of scientific superiority that had subtly primed Western elite mind-sets for the bombshell that was to be Sputnik.

Wakeup Call at the Atoms for Peace Conference

During the early 50s, the prevailing view had been that Soviet science was not to be taken too seriously, and that most of the technical strides that had been made, such as the detonation of the first Soviet nuclear bomb as early as 1949 was to be explained by a combination of espionage such as Klaus Fuchs' and utilization of captured German scientists.

An early warning of the gross underestimation inherent to this view was given by the 1955 Atoms for Peace conference in Geneva, where Western representatives were very surprised by Soviet technical competence, ground-breaking projects such as large particle accelerators, and the number of students and scientists being trained in the USSR.[16] This clashed with the belief that Soviet science was backward, delivering a first blow to Western confidence. It also led some to ask questions and push for more concerted Western effort in this area.

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[16] Krige, Atoms for Peace 2006, 178-180

DeStalinization and Soviet Outreach

After Stalin died in 1953, the process of deStalinization gradually set in marked by the crucial moment at the end of the 20th Congress of Communist Party in February 1956. Khrushchev then gave his famous 'On the Cult of Personality and Its Consequences' speech, denouncing the crimes committed during the Stalin era. This event signalled profound changes in Soviet policies, of which most relevant for the West would entail a shift from confrontational disposition to a posture more accurately typified as competitive co-existence.[17] Consequently, the direct threat is perceived as far less imminent.

At the same time, the USSR reaches out to non-aligned countries, and NATO responds in kind by refocusing on the pursuit of improving and extending NATO cooperation. For implementing this, the North Atlantic Council in 1956 asked a Committee of Three Wise Men (the Foreign Ministers of Italy, Norway, and Canada) to advise them “on ways and means to extend NATO co-operation in non-military fields and to develop greater unity within the Atlantic Community.”[18] The data mentioned on relative growth of educated manpower was also taken into consideration by this committee, and indicated an “especially urgent need to improve the quality and increase the number of scientists, engineers, and technicians” within the Atlantic Community.

Lack of Trained Manpower

A more practical concern fomenting insecurity was the overall shortage of military personnel with proper technical training. This was owed in part to the generally high demand for such skills in commercial markets; and drove home the realization that Europe was still producing less young academics than might be expected in comparison to US output. More importantly, it contrasted with the sharp rise of educational output in the Soviet Union when measured in awarded degrees and doctorates[19], as alarmingly chronicled in Nicholas DeWitt’s “Soviet Professional Manpower”. This in turn led to calls for stronger Atlantic action on this issue such as US Senator Jackson’s 1957 report: “Trained Manpower for Freedom” which concluded that NATO faced “a genuine crisis in the form of serious

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[17] Krige 2000, 88-89

[18] NATO, Summary Record of Council Meeting on Ministerial level. 5 May 1956. C-R(56)23, paragraph 64, section 1

[19] DeWitt 1955

shortages of skilled scientific and technological manpower”.[20] This concern over a lack of “Trained Manpower” played a big role in shaping the NSC, as we shall see in chapter 6.

Soviet ICBM's

In August 1957, the USSR had successfully launched its R-7: the world's first Inter-Continental Ballistic Missile (ICBM). By contrast, the US launch of its ICBM Atlas ended in failure in June 1957; it would take until November 1958 before Atlas had its first successful flight.

Sputnik

The decisive shock spurring NATO into action would of course be the successful launch of Sputnik on 4 October 1957, which was actually carried into orbit by a modified version of the aforementioned R-7 missile launched just a few months prior. However, as demonstrated through the minor shocks listed above the wheels were already in motion for a re-orientation of NATO with regards to science co-operation long before this happened. Furthermore, the Suez crisis had raised question over alliance cohesion and added to a sense of Western insecurity vis-à-vis the USSR.

With the launch of Sputnik, the NATO allies grew very concerned. The Soviets had been ahead in ICBMs allowing them to first launch a man-made satellite into orbit around earth. Compounded by all the minor shocks in a relatively short space of time so far, Sputnik caused a crisis in Western confidence in its scientific and technical superiority.

The Committee of Three had recently published their report to NATO, reminding the Council that it was conceived as more than just a military defensive alliance, but also as a values-based community of free, Western, democratic states with a commitment to human rights and rule of law: the Koepfli task force and aforementioned Jackson committee spawned by this Committee had at this moment only just reported their findings to NATO and provided a prescription to precisely those concerns worrying Western nations, which contained the broad outlines of the NSC.

Of course, Sputnik had many other repercussions, not least of which are the US founding of the Defense Advanced Research Projects Agency (DARPA), the National Aeronautics and

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[20] Krige, Atoms for Peace 2006, 199-202

Space Administration (NASA) which were to be primary actors in the Space Race. These organizations with their massive initial budgets illustrate the gravity ascribed to technological developments in the Soviet Union, and elucidate the context of NATO's response in instituting a NATO Science Committee (NSC), to strengthen western science.

3. Creation and Early Years of the SHAPE Air Defence Technical Centre

In this chapter we first consider why air defence and early warning had become so essential to NATO's military planning in Europe, secondly how this led to the call for an institution to render technical advice to SHAPE, thirdly under what circumstances it was created, and finally look at how the organization developed over its early years.

3.1 Increased Urgency of Air Defence and Early Warning

From its inception onwards, air defence has played an important role in NATO's outlook to its strategic surroundings, but the advent of Soviet thermonuclear weapons and long-range jet bombers made these aspects to its defence all the more important. We look at early difficulties in improving air defence and then examine the tactical reasons for considering these crucial.

Even before NATO's establishment its exclusively European precursor –the Western Union Defence Organization founded in 1948 and comprising the United Kingdom, France, and the Benelux countries– had already begun explorative discussions on cooperation on air defence and formed some committees on concrete problems[21]. This indicates air defence's early recognition as an important issue. In fact, in NATO's first strategic concept we find an enumeration of 'Basic Undertakings for Military Measures to Implement Defense': air operations are mentioned in every single item and neutralizing enemy air operations is singled out, featuring prominently as the third item on the list[22]. At same time, as mentioned in the previous chapter, moving air defence beyond national control to supranational institutions was politically a very sensitive issue. Why this intense focus on air operations?

[21] Dawson and Nicholson 1967, 570
[22] NATO, The Strategic Concept for the Defense of the North Atlantic Area. 19 October 1949. M.C.3

Quite apart from their instrumental role in the Second World War, the full explanation demands that we turn our gaze towards the role played by atomic weapons in NATO's strategic thinking.

In the very early years of NATO and SHAPE, strategic thinking and planning had been dominated by the experiences of the Second World War. However, the USSR had conducted its first successful test with a nuclear weapon in 1949[23] and in 1953 detonated a thermonuclear device. It gradually dawned upon planners, that the age of atomic war and jet bombers would require an altogether different defence posture as the initial stages of all-out war would involve cataclysmic nuclear exchange, dramatically altering the strategic and tactical landscape for any subsequent conventional battle.

NATO was conceived as a defensive alliance, and as such focused primarily on planning reactive military operations where the opponent would necessarily possess the initiative. In other words, NATO and thus SHAPE assumed that hostilities would be initiated by the USSR, if hostilities were to transpire at all. This lent overriding priority to deterrence, which was mainly provided by the alliance's nuclear capability. With the emergence of Soviet nuclear production and delivery capability, nuclear deterrence was no longer a decisive advantage and had to be qualified by the effectiveness with which both sides could implement it. Air defence was a crucial element to reducing the effectiveness of USSR nuclear strikes.

These considerations led General Alfred M. Gruenther to implement a new Strategic Concept for NATO upon his appointment as SACEUR, known as 'The New Approach'[24].

A key document herein was drafted by the Military Committee's Standing Group (M.C. 48), and in this outline it transpired that NATO had in the 1950s little hope of preventing a rapid overrunning of Europe if restricted to the use of conventional forces. NATO would therefore be forced to resort to atomic weapons to compensate what it lacked numerically in conventional and tactical forces[25]. The Soviets would not be unaware of this, and as such would conclude that a scenario where both parties would refrain from deploying atomic

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[23] Harry S. Truman Library, President's Secretary's Files, Naval Research Laboratory. *Collection and identification of fission products of foreign origin*. 22 September 1949. Box 200, NSC-Atomic.
[24] SHAPE, SHAPE - The New Approach (1953-1956) 1956, viii
[25] NATO, The Most Effective Pattern of NATO Military Strength for the Next Few Years. 22 November 1954. M.C. 48

weapons was unlikely. As such, the Military Committee concluded that the best course of action for the USSR would be to strike first using nuclear weapons.

The NATO allies were very concerned with the Soviet's element of surprise. Although it had a smaller nuclear stockpile and inferior strategic air delivery capability than the West, the Soviet Union might overcome this handicap by using said weapons against tactical targets crippling NATO's ability to strike back. This maximization of the advantage inherent in having the element of surprise through initiative is exactly what NATO sought to mitigate through enhanced early warning and air defence systems.

Inter-Continental Ballistic Missiles (ICBM's) were not yet a feasible method of nuclear delivery (though it should be noted that the earliest effective Theatre Ballistic Missiles (TBMs, a category comprising Short-Range, Medium-Range, and Intermediate-Range Ballistic Missiles) had become available during WWII already, and the imminent advent of ICBMs was clearly foreseen), and as such the primary threat consisted of long-range, high-altitude strategic bombers, much like the B-29 Superfortresses that delivered the Little Boy and Fat Man scarcely a decade earlier.

Air Defence vis-à-vis Early Warning

Because effective ground-based air defences were lacking, and there was an enormous shortage of interceptor fighter aircraft, early warning would feature quite prominently within the strategic outlook of the early 50s.

The reason effective defence against bombing runs was problematic, was that anti-aircraft guns were mostly useful against targets at low altitude (as ballistic projectile defences tended to have limited range and dramatically reduced accuracy even if ramped up to higher powers) with limited speeds. Even during the latter stages of WWII, over 90% of propeller-driven bombers made it through AA-measures, based on altitude. By 1953, the Soviets had started incorporating high-altitude bombers with modern jet engines into their operational arsenal. Owing to the short time window in which flak cannons can be fired at such fast targets, the odds of a hit against enemy strategic jet air forces would diminish to a statistical curiosity.

In response to this, radar guided Surface-to-Air Missiles (SAM) were under heavy development: the US and the UK had moved to invest heavily in projects such as NIKE and HAWK, both regarded SAM-systems. However they hadn't reached the stage where they could be operationally deployed in numbers yet. Therefore, air defence rested mostly on tactical Interceptor Air Forces, but NATO was faced with grave deficiencies in this aspect with the USSR vastly outnumbering it in terms of tactical aircraft.

How did Europe end up with such grave deficiencies in terms of tactical air forces? NATO Europe in 1949 was mostly focused on economic recovery and was divided with regards to standards and interoperability. The predictable result was proliferation of deficiencies in Europe across the whole board. This held true even after accelerated investments following the Korean War. In each and every category of warplanes, of the number demanded by SHAPE's force requirements, less than half were available in the defence of Europe as late as October 1954[26]. The number of interceptor aircraft available capable of flying in bad weather conditions and during nighttime was particularly insufficient.

Whilst augmenting these numbers were a matter of priority, in the meantime much focus was placed on implementing systems to assure prior warning at the earliest stage possible, so as to initiate a swift retaliatory counter strike. This could be effective as NATO did still have a preponderance in strategic air forces and nuclear delivery capability. Furthermore, such warning allowed NATO to minimize damage through passive defensive measures such as target dispersion: the loss of an airfield is less devastating if its aircraft aren't present. In other words, the best that NATO could hope to do was minimize damage and maximize the retaliation to improve the odds of coming out on top in an early phase of nuclear exchange. For both aims, early warning across the countries of Western Europe was crucial.

3.2 An American Initiative

In this short section, we explain how the idea and initiative which led to the SADTC being created as part of the answer to the above questions, came from preceding US experiences and institutions.

In the US 'Continental Early Warning and Air Defense' had been considered an important issue by the US Air Force in prior years (from 1947 onwards)[27] and development towards systems such as the Distant Early Warning (DEW) Line in Arctic Alaska and Canada and

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[26] SHAPE, *SHAPE Study on Air Defence in the NATO Area of Europe*. 23 October 1954. SHAPE/626/54 (AG 1250 CS), paragraph 121
[27] Redmond and Smith 2000

the Semi-Automatic Ground Environment (SAGE) computer network had already progressed much farther than anything of the sort in Europe. These experiences would form the basis for the idea of a European counterpart.

In the development of US early warning systems, a central role was played by the United States Air Force's Scientific Advisory Board (SAB), and the initial idea was basically to replicate this in Europe. Interesting to note is that the SAB was in the late forties and very early fifties headed by famous aerospace engineer Theodore von Karman who was instrumental to establishing SADTC's only precursor in terms of research institutions within NATO, AGARD, in 1952 (see section 7.1). The dynamic leading to SADTC thus very clearly originated around the SAB.

In 1953 the idea for an electronic centre for SHAPE was first proposed by the Electronic Panel of the SAB[28]. Following a preliminary exploration in Europe, early in 1954, the US Air Force instituted a planning group headed by Carl F.J. Overhage to study the proposal of establishing such a centre and the best method of doing so. In June 1954 this group visited Europe and held discussions on the idea with various NATO countries concerned meeting with, in general, favourable response. This work would form the basis for SADTC.

The Overhage group's findings were published in September and SACEUR Gruenther was found to be very receptive to the ideas in the Overhage Report. The General had been instructed in December 1953 to inquire into the problems of air defence and early warning by NATO's Military Committee and grown convinced that the problem was so complex as to require a larger group of experts supplying technical advice to have any chances of successfully completing anything approaching a comprehensive study of the subject matter. A permanent Technical Centre with a staff of experts devoted to this subject area aimed at supplying SHAPE and SACEUR with technical advice was the logical extension of this.

By October NATO's Secretary-General was on board and early November the 'SHAPE Air Defence Technical Centre' was announced. Funding for the initial years was to be supplied by the US Mutual Weapons Development Program, although the Centre would be

[28] SHAPE, SHAPE - The New Approach (1953-1956) 1956, 240

completely answerable to and at the service of SHAPE from the outset. NATO was to have the choice of whether or not to take over the Centre at the end of US funding[29].

This was not without precedent, as NATO's Advisory Group for Aeronautical Research and Development (AGARD) mentioned before as another initiative with strong SAB-ties, had been set up along similar lines a few years earlier; mostly this was greeted positively, although some civil servants within the UK Treasury were sceptical and appear to have perceived the US initiative as partially coercive rather than generous.

3.3 The Creation of SADTC

We briefly discuss how the creation of the SADTC was done bilaterally between the US and a Dutch contractor with assent from the Netherlands government and SACEUR. This shows what stakeholders were involved in defining the organization's initial terms of reference.

The US Government established the Centre by entering into a direct contract with the National Defence Research Organisation of the Netherlands Organisation for Applied Scientific Research (RVO/TNO) instructing the organisation to establish physically and organisationally the SADTC in The Hague for a period of three years with a budget of $2.5 million, and see to its operation. Whilst SADTC was to be a separate entity from RVO/TNO, the latter was expected to make available all its facilities to the use of SADTC.[30] Separately, the US also entered into an Agreement with the Netherlands Government to secure certain rights and guarantees for the status, operation, and security of the Centre on Dutch territory.

The SADTC, whilst enjoying a certain degree of autonomy in directing its research efforts, was to be directly answerable to SACEUR for its assignments and programme of work, and featured an Advisory Committee with representation of all nations in NATO. Since the US was bankrolling the operation, some advisors and financial officers were also stationed at SADTC. Through this construction then, even though the centre operated in the service and interest of the alliance, the North Atlantic Council had in a strict sense no direct say in its work.

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[29] SHAPE, US Assistant Secretary of Defense Donald A. Quarles, *Memorandum for Alfred M. Gruenther, USA – SHAPE Air Defense Technical Center*. 2 November 1954. RD 276/1

[30] Netherlands National Archives (afterwards NL Archives), Netherlands Ministry of War, *Bespreking betreffende het Air Defense Technical Center*. 4 December 1954. 2.13.142/668 – Verslag 481

From outset, the intention was for the SADTC to be initially transferred to direct NATO Control, and Common Financing. There was some resistance to this from some quarters; notably internal memos in the archives of the United Kingdom's Treasury relates the following exchange between two civil servants, Mr Williams and Mr Allen, which is telling of the suspicion with which this initiative was viewed in some quarters. Williams: "Since we are not contributing, I do not think there is much we can do, save murmur darkly about the cuckoo in the nest." Allen: "How? To whom?" Williams: "Ourselves I fear"[31]. In other words, it was futile to resist since the US was paying the bills for the first couple of years and there seemed broad consensus amongst defence authorities that the centre would be militarily expedient.

3.4 Subsequent Evolution of the SADTC

In this section we first describe how the SADTC grew dramatically during its early years, both with regards to financing as with regards to premises and staffing. Secondly we consider the decision to move it towards common financing, as was originally intended by the US, and finally we look at the eventual shape the centre was to take as a full-fledged international organization under the name of SHAPE Technical Centre. All of these steps illustrate the great utility SADTC/STC represented to SHAPE, and the potential for further use that was seen.

Early Growth

Throughout its early years, the SADTC payroll grew drastically, showing the legitimacy and faith it enjoyed. Staff increased from a handful of employees at its start in 1955, to 66 by early 1956, and quickly expanding to 127 staff by mid-1957 of whom 31 were 'full-blooded scientists' and a slightly larger number technical support personnel.[32] By the end of 1960, the ranks of the scientific staff had more than doubled once more, swelling to a planned 80 scientists and 300 staff total for the 1961 Work Programme leading to significant problems surrounding accommodation.[33] It was agreed by the Committee of National Representatives that owing to the great importance of the SADTC's work for the alliance and its extensive

[31] UK Archives, note found within H.M. Treasury, *SHAPE Air Defence Technical Centre*. 17-Dec-54 to 21-Dec-59 T/225/2478.
[32] UK Archives, Report made by Mr. P.S. Ziegler of his visit to the SADTC. 1 August 1957. T/225/2478, paragraph 8
[33] NATO, SADTC Committee of National Representatives (afterwards SCNR), *Besoins du CTDAS en Locaux*. 16 December 1960. AC/165-D/7, paragraph 1

programme of work, the proposed 80 scientists would be approved, a future ceiling of 100 scientists would be imposed on the centre.[34] This is indicative of the relevance of the SADTC's work to SHAPE, especially since this last decision falls within the era of common financing.

In terms of money for the first three years of operation, the US MWDP awarded SADTC $2.5 million in funds, and for its extended services up to 1959 the figure was increased to $5.5 million. This however, did not include the costs for extra projects undertaken by SADTC not within its own budget. By late 1957 the UK Mission to NATO HQ estimates SADTC's annual costs to run between 3 tot 5 million US dollars, and by 1960 this estimate rises to nigh 10 million annually.

For the Netherlands, this was a significant and important influx, however when compared to the $9 billion of Defence Aid heaped on Europe by the US, it is a rather insignificant amount. However, a direct comparison is not entirely called for, as whilst the source of the money may be the same, the direct support of rearmament (which to some extent entailed the European purchase of old American equipment) is qualitatively a rather different thing than the direct support of a technical research institute. Considering the great expansion in activities and personnel the centre was able to realize in a short amount of time, the reasonable conclusion must be that support was generous and significant. In other words, the US put its money where its mouth was in praising the centre.

Transfer to NATO in 1960

SADTC ran into some trouble towards the initially foreseen end date of its US financing in 1957, staff were getting anxious about their future without explicit assurances that NATO would adopt the centre and move it to Common Financing for its continued operation (and the continued employment of its staff).[35] Whilst there was some dragging of feet, the global recognition of its utility led to the organization's continued existence, even under common financing.

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[34] NATO-SCNR, SADTC Programme of Work 1961 – Introduction to Work Program and Policy Guidance. 4 November 1960. AC/165-D/2 ANNEX II

[35] UK Archives, Letter from UK Permanent Representative at NATO HQ (Mr. A.L.M. Cary) to Mr. F.A. Kendrick (UK Ministry of Defence). 30 October 1957. T/225/2478, 23027/ /57.

SACEUR strongly supported its continued operation identifying it as a 'vital interest', however whilst there seemed to be a general recognition of its operational utility and military necessity it was not so easy to reach agreement on the exact mode of financing the Centre should receive and whether it should be directly referred to the Military Budget Committee or whether some sort of Ad Hoc Committee was to be established to discuss its future status. Eventually the US extended its financing for the Centre until 30 June 1960 and the 'Working Group on the Future Status of the SHAPE Air Defence Technical Centre' was established.

Broadly speaking, the Working Group considered three possible solutions to SADTC's future status after the termination of RVO/TNO's contract with the US Government[36]:

1. Retention of the current structure, with NATO and RVO/TNO signing a contract similar to the one in force between NATO and RVO/TNO.

2. Continuance of the Centre as a Netherlands Foundation with elimination of RVO/TNO as a middle man.

3. Transformation of SADTC into an international organization, and as such a proper subsidiary of NATO.

Option 3 was rejected because new regulations and the more generous staff compensation such a route entailed would make running the Centre more expensive. Additionally, it was felt such a drastic organizational change would disrupt the important work being done within SADTC.

It was stressed that the role played by RVO/TNO during the first five years of SADTC had been much appreciated; the organization had provided good support, and facilitative services at favourable conditions (such as the bookkeeping). Moreover they ensured good contacts with the host country's government, and had managed live within its means cost-wise.

In the final analysis, the desire to disturb the Centre's research as little as possible, limit operating costs, and appreciation of the services rendered by RVO/TNO led the Working Group to opt for the first option, as had been favoured by the Dutch authorities (who valued the Centre's relative independence in research matters and separate identity from SHAPE),

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[36] NATO, Working Group on the Future Status of S.A.D.T.C. *Questions for discussion*. 23 October 1959. AC/155-D/1.

as evidenced by Mr Cary's recollection of a visit to his office in Paris by Hugo de Groot (presumably with the Dutch mission at NATO HQ). In addition the Advisory Committee was abolished, whose role was to be supplanted by the Committee of National Representatives (CNR) would be strengthened, through more direct involvement in approving Programmes of Work and submitting these to the Military Budget Committee for approval.

SADTC becomes SHAPE TC

However the new arrangement would not last long, Air Defence was too narrow and no longer covered SHAPE's need for technical advice. As one British observer remarked as early as 1957: "The words 'Air Defence' in their title are more an indication of the nature of their general duties than a limitation of their functions."[37]

The new contractual arrangements between NATO and RVO/TNO had complicated matters a great deal, and as such the link was eliminated altogether although the premises were kept (and are still in use today). SACLANTCEN had proven useful to the Supreme Allied Command Atlantic in furnishing advice on a wide variety of topics, leading to requests within SHAPE for a more general Technical Centre of their own. Finally, the NADGE controversy had put the SADTC in an awkward position.[38]

SHAPE Air Defence Technical Centre became an international military organization which fell directly under the command of SHAPE starting 1 March 1963, known simply as SHAPE Technical Centre (STC).

In summary, with the US loss of nuclear monopoly, defence against air operations and retaliatory speed were essential to the outcome of the first nuclear exchange stage of a large-scale conflict. Early warning was not just essential for actual defensive capability but also played a big and visible role in deterrence by displaying the capability to strike back swiftly and decisively. Direct forms of defence, even if only partially effective, were also quite important because of prospective future scenarios where counter strikes weren't going to land. If so it would be unacceptable if Soviet strikes went uncontested. Secondly, the nuclear

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[37] UK Archives, Report made by Mr. P.S. Ziegler of his visit to the SADTC. 1 August 1957. T/225/2478, paragraph 6.
[38] Dawson and Nicholson 1967, 586-588

defence scenario gave considerable difficulty in the case of *limited wars* where the USSR made incursions on a scale that couldn't really justify nuclear counterattack.

This tactical background provided a clear reason for the establishment of a technical centre such as the SADTC, and it was those institutions which had been involved in their initiation in the US that took the first concrete steps towards its realization in Europe. Whilst there was some concern about details of financing and conflicts with national interests, there was broad consensus and support for the SADTC's formation and subsequent expansion; provided it did not actually engage in weapons development and limited itself to providing advice to SACEUR and various technical services of course.

4. Challenges of Air Defence and Early Warning

This chapter will delve into some of the challenges SADTC saw itself faced with in the fifties, and discusses the solutions it had to implement. In section 1 we discuss the importance of air command and control, section 2 deals with active air defence. Section 3 is the focus of chapter 4 and considers the elements of early warning, placing these into 3 subsections on radar detection, data handling, and communications systems respectively. As such a reasonably comprehensive qualitative description of the sort of work done at SADTC is attempted.

4.1 Air Command & Control

The most reliable mode of defence against attacks from the sky was the use of air forces to intercept enemy planes. However, as aircraft speeds rose, feasible timeframes for response dwindled, and relaying fast and accurate information to such forces became increasingly important. In 1948 already, the US Air Force had reached the conclusion that supplying airplanes with information was a task that could not be left up to human operators on the ground for much longer.[39] Furthermore, jet planes had become so fast that it was becoming quite difficult for pilots to actually get behind an opponent, as turns had to be initiated whilst still miles away from the target. It was recognized that delays caused by human operation were unacceptable here too, and that this issue known as 'the Air Intercept

[39] Redmond and Smith 2000, 13-14

Problem' would require some degree of automation. This had such great priority that seven-digit sums of funds were available for the development of computers on the ground designed to automatically guide interceptor aircraft to their quarries[40].

As discussed before, anti-air artillery had become impractical due to increased cruising height and speed of aircraft (jet bombers were in particular were considered a big threat) as this at once both increases the number of flak shells statistically required per hit on target on one hand and on the other hand reduces the time duration within which targets remain in range and effectively reduces the number of shells that can be fired. Surface-to-Air missiles however did not suffer from these problems, as their range is much greater and they can (crucially) adjust their flight path after launch, using either or both integrated homing devices and ground-based radar systems to find their target. Furthermore, these missiles would have the capability of attaining much higher speeds and could be computer controlled without the delay of an intermediary human pilot. Thus such missiles offered to solve the problem of the limited efficacy of ground-based anti-air defences. Another consideration was its ability to seek out and destroy Theatre Ballistic Missiles (encompasses Short-Range, Medium-Range, and Intermediate-Range Ballistic Missiles). Later with the advent of the first ICBM's in 1957, studies would be undertaken to test the prospect of interception of such weapons.

Most of the problems concerning Air Control were related to Data Handling. Information from a variety of sources had to be collected, and used in the calculation of directions towards the fulfilment of specific tasks and goals. Very significant investments were made in computing technologies, so much so that this is considered an important reason for IBM's dominance in subsequent decades[41], however a detailed discussion of all the extensive work on computer systems and the impact of solid state systems would be far beyond the scope of this thesis.

4.2 Active Air Defence

In the realm of active air defences, SADTC did very limited work in terms of actual Missile development. Most of this work was beholden to the laboratories and industrial complexes of the larger individual member states, notably the US and the UK. Such nations had little interest in forgoing control over such crucial R&D projects, and indeed it may be argued

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[40] Ibid. 17-18

[41] McCamley 2013, Chapter 2

that such work was both beyond SADTC's abilities given its humble scale and its terms of reference, which provided first and foremost its consulting role in rendering technical advice to SHAPE concerning Early Warning and Air Defence challenges. SADTC did have an important role to fulfil in their implementation however, as such systems could not be trivially transported to and installed on European soiled but needed to take account of the terrain and strategic environment and be integrated in the much wider Air Defence infrastructure. To that end, SHAPE sent orders to the SADTC in 1956 to study the feasibility of implementing its Nike Hercules B system in Europe, and to develop a plan/proposal for how to do so[42]. This will be described further in section 3 of chapter 5.

As detailed in the first paragraph of chapter 2, in the age of nuclear war, the absolute earliest possible warning was essential to the successful prosecution of a war conducted from an initially defensive posture. The earlier SHAPE Command could be made aware of a threat, its nature, and its location, the earlier counter-measures can be implemented, such as the launch of interceptor aircraft, passive defence through the dispersion of likely targets (such as strategic bombers), and the launch of retaliatory counter-strikes to cripple the opponent's capability of sustaining attack as soon as possible.

In this chapter we will discuss the main obstacles SHAPE faced in the mid-50s towards attaining this capability to an acceptable degree, how the SADTC was involved in the implementation thereof, and the physics behind the technical solutions employed to achieve this.

4.3 Early Warning

In order to have early warning of inbound threats, i.e. to operating an effective EW system, there are 3 steps essential:

1. Threat Acquisition (Radar detection)

2. Data Handling (Computational processing)

3. Data Transmission (Communications)

[42] SHAPE, *Guided Missiles in Air Defence – Release of Information to SHAPE*. 31 January 1956. AG/6441/AD. This letter refers to the letter sent a day earlier (in footnote 83) and calls attention to the specific project of Guided Missiles.

First off, a threat needs to be detected by one of the radar systems. Preferably as early and as reliably as possible, which has implications for radar range and resolution.

Secondly, central command needs to know of it immediately. Which means the information needs to be transmitted quickly, and reliably (downtime is not acceptable), potentially from Norway or Turkey (or both), all the way to SHAPE HQ in Paris. This implies a dedicated system (for speed) that is relatively hard to jam.

Prior to data transmission however, bandwidth limitations entail that the essential data must be distilled from raw radar output. Given short timeframes dictated by high-speed jet bombers, time is of the essence so automation is important. Furthermore, there is the potential of a great many incoming targets, whose positions and bearings will not be constant, which adds to the arguments for automating the job of data handling (which was mostly done by humans during the WWII, see picture).

All of these represent challenges for the envisaged SHAPE Early Warning System, in which SADTC was involved to varying degrees. As we shall see, whilst they contributed to the resolution in all of these questions and drafted the Radar Plan SHAPE would eventually adopt, a great deal of the actual technical work was contracted out, and their most significant contributions were in the area of communication through implementation of the ACE-High[43] troposcatter network.

4.3.1 Radar Technology

Radar Basics

Radar, originally an acronym for 'RAdio Detection And Ranging', is a system utilizing radio waves to detect objects at a distance by exploiting the fact that objects (particularly conductors, owing to their free electrons) will scatter a small portion of a transmitted radar beam back to a receiver station. The technique was first developed and demonstrated by Christian Hulsmeyer who used his 'telemobiloscope' in 1904 to detect a metallic object[44]

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[43] ACE is an acronym for Allied Command Europe, ACE High was a NATO communications system spanning Europe that was an integral part to SHAPE's Radar Plan.

[44] Hulsmeyer, 1904. Patent DE165546: Verfahren, um metallische Gegenstande mittels elektrischer Wellen einem Beobachter zu melden.

and later that year to detect a ship in dense fog[45]. Development picked up pace in secrecy within several nations during the thirties leading to its widespread utilization during WWII, the most famous application being the British Chain Home system utilized to great effect during the Battle of Britain. In the discussion below, we shall limit ourselves to monostatic radar systems, which feature transmitter and receiver at the same location.

<u>Scattering and scattering cross-section</u>

In order for radar to work, the target must scatter some of the radio waves sent its way back to the receiver. The quantity which determines how much is scattered back (and thus, how strong your response is going to be) is called the scattering cross-section, also known as the radar cross section.

Scattering cross-section is defined as the surface area an object capturing and scattering the radar waves appears to have, making the highly idealized assumptions of an incident plane wave which is re-radiated isotropically.[46]

$$\sigma = 4\pi \frac{Power\ towards\ receiver\ per\ unit\ solid\ angle}{Power\ per\ unit\ area\ incident\ at\ target}$$

Which may be more formally defined as

$$\sigma = \lim_{R\to\infty} 4\pi R^2 \left(\frac{E_s}{E_i}\right)^2$$

The dimension of the scattering object relative to the wavelength of the radio waves used are essential to the radar cross section found, as one moves from relatively large wavelengths and the Rayleigh-region towards comparable scales in the Mie-region and finally settling in the optical region. Most convenient is usually the optical region where

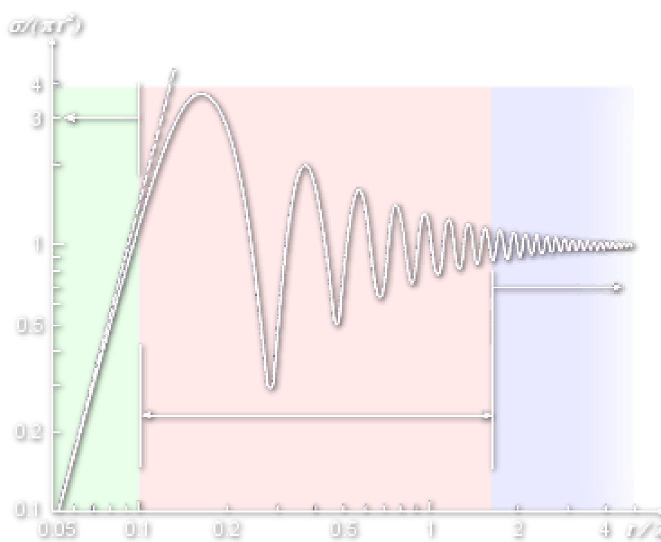

Figure 2: Scattering Cross Section as a function of Wavelength, Source: The Radar Tutorial

[45] Hulsmeyer, 1904. Patent DE169154: Verfahren zur Bestimmung der Entfernung von metallischen Gegenständen (Schiffen o. dgl.), deren Gegenwart durch das Verfahren nach Patent 16556 festgestellt wird.
[46] Fuhs 1983

wavelengths are much smaller than the target objects.

Another important factor is obviously the precise shape of the scattering object. In the case of a sphere of radius *r*, matters will be simple and we obviously find a scattering cross-section equal to its apparent 2 dimensionally projected surface: $\sigma=\pi r^2$, however for a circular cylinder of length L and radius r, one already has to account for the angle θ of the incident plane wave to the axis of the cylinder, and we find[47]:

$$\sigma = \frac{r\lambda}{2\pi} \frac{\cos(\theta)\sin^2\left(\frac{2\pi L}{\lambda}\sin(\theta)\right)}{\sin^2(\theta)}$$

Naturally, real world scattering object do not fulfil such nice idealized conditions, and the determination of radar cross sections was a topic that received a lot of attention during the early Cold War, though as far as archives available show SADTC only engaged in compiling such information acquired by individual nations, rather than determining these cross sections themselves. Therefore, we shall not delve any deeper in the procedures adopted to their measurement, and rather use this conceptual working notion of radar cross-section to derive the radar range equation. But first a brief discussion of pulse operation of radar is in order.

Pulsed Radar

Whilst the earliest continuous-wave radar systems had some limited capabilities in terms of object-detection and even rudimentary ranging through the utilizing of beat methods, radars comparable to their modern counterparts emerged with the advent of pulsing. It was shown in 1934 that short, powerful, evenly spaced pulses permitted much higher illumination intensity without significantly increasing the total time-averaged power and furthermore offered a simple method of ranging a detected object, by virtue of the finite speed of

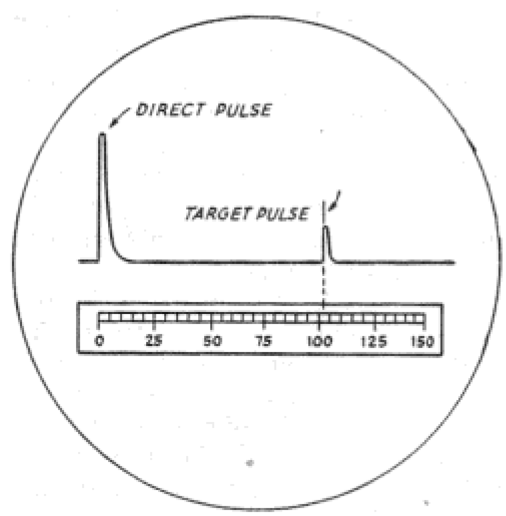

Figure 3: Distance Determination with Pulse Radar
Source: Page 1962

[47] Skolnik 2008

electromagnetic radiation[48]. In the simplest conceptual notion, one might imagine transmitter and detector tuned to the same radio frequency located at the same position. Every transmitted pulse will be picked up directly by the detector, and any reflections of that pulse will be picked up with a time delay given by:

$$\Delta t = \frac{2 \cdot d}{299458792}$$

Where *d* is the distance in meters of the reflecting object. By converting the electrical signal driving the periodic pulsation of the transmitter to a sawtooth shape signal, this voltage may be used as the horizontal deflection in a Cathode Ray Tube (CRT), providing a time basis in sync with the generated radar pulses. Using the detector's response for vertical deflection off of the horizontally scanning time base, the time difference between the direct detection and reflections may be directly measured on the screen. Naturally, whilst simple in principle, many practical obstacles surrounded the realization of such a system: Most notably that it was technically very hard to achieve the radio signals required, given the radio wavelength, pulse frequency, pulse width, and power desired. Another limitation was the large antenna generally required, rendering radar impractical, vulnerable, and unwieldy. Two technological developments conspired in the late thirties and early forties to address these issues: Improved electronics through the rapid development of vacuum tubes and CRT's on one hand, and the development of the resonant cavity magnetron on the other.

Resonant Cavity Magnetron

The first cavity magnetron which set of America's intensive R&D programmes was introduced to US shores in August 1940 by Sir Henry Tizard. Not only did these devices make it possible to generate microwaves at short wavelengths with tremendous power compared to what was achieved before, they furthermore were relatively sturdy and compact, allowing for portable radar systems to be installed in warplanes. For these reasons, the magnetron was absolutely crucial in the

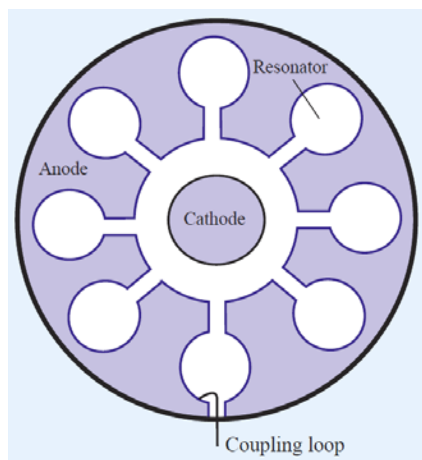

Figure 4: Magnetron diagram

[48] Page 1962

torrential development of radar technology and applications from that moment onwards.

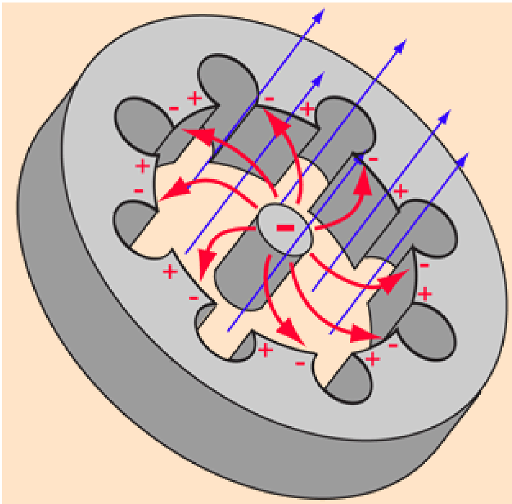

Figure 5: Magnetron with electron flow (red) and magnetic field lines (blue)

The mechanism behind the magnetron is deceptively simple, the constant magnetic field causes the electrons that escape from the anode to undergo a sweeping circular motion, thereby alternately adding charge to either side of the cavity's inside the cathode. This caused currents around the cavity's to be pumped, giving rising to an alternating electric and magnetic field in the cavity, resonant with the cavity, thus causing electromagnetic radiation at the frequency selected when designing the magnetron and deciding on cavity size.

Radar Range

For a reasonable first approximation of maximum radar range (neglecting all the other factors such as statistical effects that need to be accounted for[49]), we can postulate a common transmitting and receiving antenna of gain G, denoting transmitted and received signal power as P_t and P_r, then for a target of cross-section σ at range R, illuminated by wavelength λ, we find that the received power P_r must be equal to the signal power density at the target $\frac{P_t G}{4\pi R^2}$, multiplied by the fraction that is scattered back and intercepted by the antenna $\frac{\sigma}{4\pi R^2}$, and finally multiplied by the gain of the antenna $\frac{G\lambda^2}{4\pi}$.

Solving this simple equation for the range R we find[50]:

$$R = \sqrt[4]{\frac{P_t G^2 \sigma \lambda^2}{(4\pi)^3 P_r}}$$

Next, we assume that P_r is at the minimum detectable value. To do so, we must somehow introduce noise or sensitivity as otherwise under these idealized circumstances there would be no maximum range for radar! We define the minimum signal-to-noise power ratio using pre-

[49] Norton and Omberg 1947

[50] Swords 1986

detector system noise P_n as $\left(\frac{S}{N}\right)_{min} = \frac{P_{r(\min)}}{P_n}$. We finally define the noise as $P_n = T_s\ B_n\ k_B$ where k_B is the Boltzmann constant, T_s the system noise temperature of the receiver, and B_n the receiver noise bandwidth, we find as the maximum range:

$$R_{max} = \sqrt[4]{\frac{P_t G^2 \sigma \lambda^2}{(4\pi)^3 \left({}^{S}/{}_{N}\right)_{min} T_s B_n k_B}}$$

Many other factors could be introduced to render this equation more accurate, however we have already come far enough to see that in order to double a radar's theoretical maximum range, its power needs to increase sixteenfold[51]! This, along with the need for short wavelengths in order to operate in the optical scattering region, illustrate quite clearly how immensely important the magnetron was for the dramatic impulse radar development received halfway the twentieth century.

Detection challenges

To say these developments had rendered radar practical enough so as to become operationally useful during the Second World War would be an understatement. The immense utility radar systems attained in a very short space of time is attested to by the sheer size of US investment in radar technology, by the end of WWII over $3 billion had been spent on the research of and equipment for radar systems[52]; by comparison, the Manhattan project cost around $2 billion.

However, radar still struggled with low-flying aircraft, Electronic Counter-Measures (ECM) had been developed to reduce its effectiveness, and as the earliest possible warning was desired, the quest to push the boundaries of range limitations continued.

A very simple technique that was actually implemented in the radar stations of the ACE-High network, was a second continuous wave radar specifically for low heights which detected Doppler shifts; this would be able to distinguish low-flying aircraft from the many ‘clutter’ objects that would show up on a pulse radar. Some of the other challenges are detailed below.

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[51] That this is correct is easily realized when one considers the area associated with a certain solid angle increased with the square of the radius, leading to a

[52] Mendelsohn 2003, 191

Radar Horizon

One of the fundamental restrictions on radar detection is the curvature of the earth, leading to a limited line of sight. This means that a radar system mounted at a height H will only have unrestricted vision up to some horizon distance D , dependent on the radius R of the earth:

$$D = \sqrt{2 \cdot H \cdot R}$$

From this distance onwards, a so-called 'radar shadow' occurs initially only occupying low altitude, but steadily increasing in height as the distance increases past radar horizon D.

This restriction is somewhat lessened by the drop-off in atmospheric density with altitude, and it's concurrently decreasing index of refraction with increasing beam height, leading to a slightly curved beam path towards the surface of the earth. This effect is accounted for by using an effective radius *R* a factor 1.33 larger than the earth's[53]. Whilst this effect does diminish the 'dead zone' or radar shadow, it does simultaneously introduce new difficulties with accurate determination of object distance and altitude.

Airborne Early Warning Radar

One of the most direct and effective methods for dealing with the range limitations imposed by line of sight is dramatically increasing the height through airborne mounting the radar system. The earliest examples of such systems entered regular service as early as March 1945, and this solution continues to be used up to this day.

Over-The-Horizon (OTH) Radar

Another strategy for dealing with this fundamental range restriction is the skywave solution. Bouncing radar signals off the earth's ionosphere (or skipping) allows detection without a direct line of sight. This phenomenon was already long-noticed in radio broadcasting, and we will come across it in paragraph 3.3 in mentioning Tropospheric and Ionospheric Scatter Communications.

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[53] Radar Tutorial, *Radar Line of Sight*. http://www.radartutorial.eu/07.waves/wa16.en.html (date accessed: 10/7/2014)

Two important drawbacks in radar application: 1. Complex problem of interpreting backscattered signal, 2. EM-wave frequency must typically not exceed the plasma frequency (dependent on density of free electrons in ionosphere), limiting the radar spectrum available with this technique to a range associated with low-accuracy radar.

Radar Polarimetry

Linear polarization of radio waves was initially seen as something as a nuisance in radar systems, and most effort went into determining which polarization would minimize clutter response, but its immense potential utility in acquiring information about the scattering object was soon realized.[54] SADTC did some limited work in analysing the value of such polarimetry, and organized a conference on the subject in the sixties.

ECCM

Electronic Counter-Measures (ECM) developments made radar data less useful and reliable and called for appropriate and effective Electronic Counter-Counter-Measures (ECCM). One of the ways to deal with enemy attempts at confusing radar systems, is to get more information and more detailed information, for instance through the polarimetric techniques in radio wave generation and reception analysis.

One concrete example of SADTC work in this field are symposia organized on ECCM-techniques in the late fifties, and furthermore the programme of work indicates SADTC mostly restricted itself to monitoring developments and studying implications for future radar systems in a more general sense.

4.3.2 Data Handling

For effective use of the warning afforded by radar, and maintaining a tactical overview, it is necessary to collect and combine all gathered data in one place.

Raw data would first be processed and made suitable for transmission, so some processing needs to occur on-site before data in a more useful and manageable format is passed on to central command and control.

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[54] Melvin and Scheer 2012, 589

There were some clear limitations in the early days of computing though, these are the days of vacuum tubes and very early semiconductor/solid state diodes. Generally programmable computers with clear hardware/software distinction were not available either, so NATO would have been very dependent on specialized products being contracted out to and developed by US suppliers. Highly specialized custom-made systems for such purposes include Whirlwind, MITRE, and the Dutch TELEPLOT system.

4.3.3 Communications Systems

Crucially, data acquired by reliable radar systems with a good range, and processed into a useful format had to be transmitted fast and reliably. This was the main issue in realizing an effective early warning system. In delivering a Progress Report at SHAPE in 1956, General Gruenther recalled: "I had occasion on about the 24th of January 1951 [...] to put through a telephone call from Paris to Oslo, Norway, which was to be one of our subordinate headquarters. I was told by the telephone operator that it would take about eight hours to get through and I was warned that the call would be routed through the Soviet Zone of Germany and we would, therefore, have Communist assistance in completing the call."[55]

The ACE High system that was planned from 1955 onwards and completed by 1963, sought to place NATO communications on the European theatre on a more solid footing. It comprised an extensive network of communication links utilizing varying technologies, employing as its backbone a troposcatter network covering NATO-aligned Europe from Senja in North Norway, all the way to Diyarbakir in East Turkey.

4.3.3.1 Basics in Communications

Initially, commercial telephone/telegraph lines and radio utilized for the communications of Allied Command Europe (ACE). This entailed many jumps, at times quite serious delays, and limited bandwidth.

It was decided that SHAPE should have its own dedicated military communications infrastructure. In order to make jamming less of a threat, and reduce the number of nodes

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[55] SHAPE, *The Defence of Europe – A Progress Report*. 1 March 1956. Typed out speech by General Gruenther, no archival reference number/code other than a handwritten notice: "4001 Gruenther".
Filename: '20121128_19560301_NU_The_Defence_of_Europe-A_Progress_Report_by_SACEU.pdf'

involved, the choice was made to rely on Tropospheric and Ionospheric Scatter communications systems[56] as the backbone of this new communications system: ACE High.

Analogously to Over-the-Horizon radar, Forward Scattering techniques had the advantage of achieving vastly superior range, as displayed in the chart above.

4.3.3.2 Boundaries/Challenges

Three concrete problems with regular radio-transmission:

1. Limited distances possible using SHF and UHF microwaves, many nodes makes the system more vulnerable.

2. Interception & Jamming possible

3. Reliability.

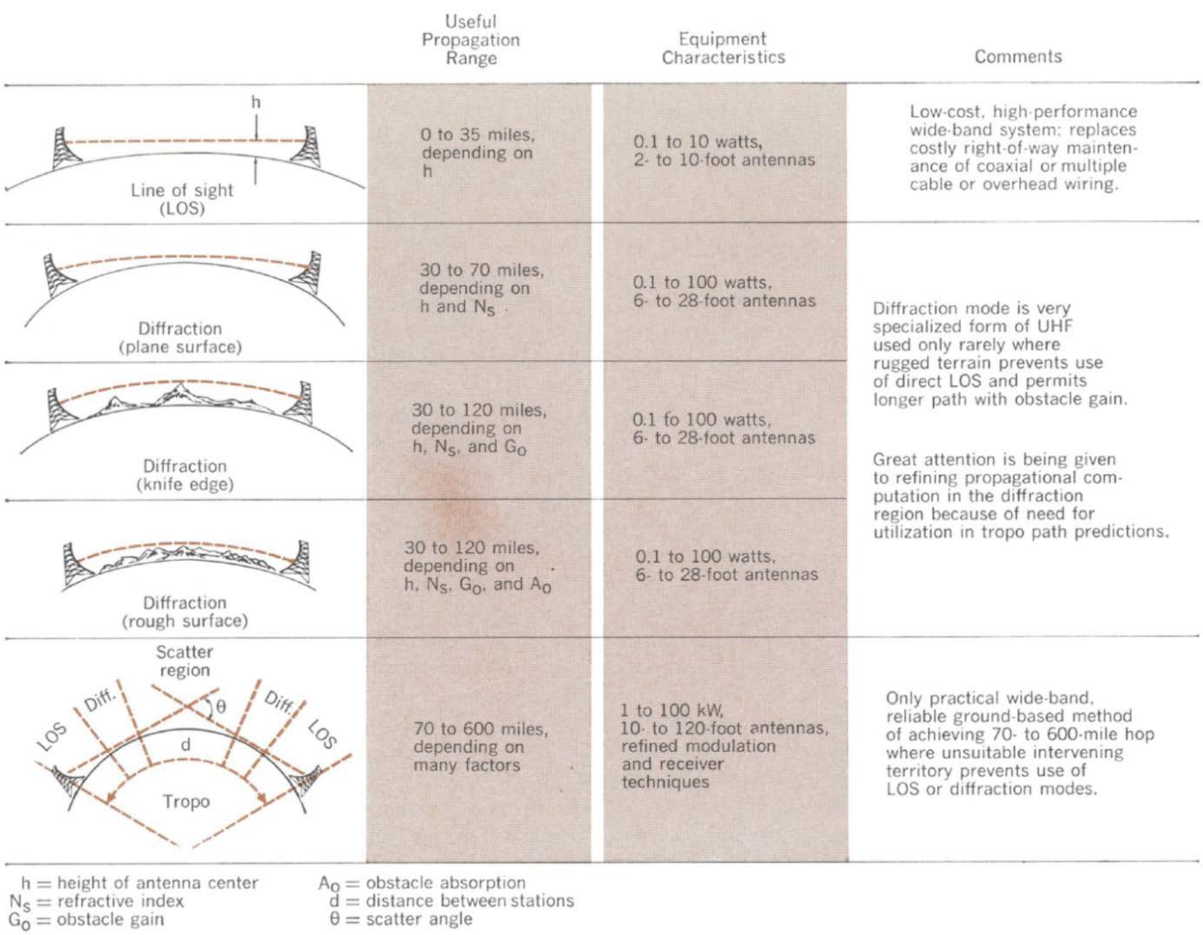

Figure 6: Communications Systems Comparison. Source: Gunther 1966

[56] Advisory Committee 1960

As illustrated in figure 6, tropospheric & ionospheric scattering offered a handle on these problems. The complication added was that the exact mechanisms of turbulent scattering were not exactly understood, and it required some statistics and processing to deal with the non-trivial fluctuations.

4.3.3.3 Tropospheric Scattering

We shall give a brief background of the technique of tropospheric scattering (usually abbreviated to troposcatter or forward scatter), firstly historically and secondly technically. This will show why this relatively new and expensive technology was useful. Thirdly, we shall summarily argue the need for location-specific studies to be undertaken for the implementation of any system. The to-be-indicated importance of this aspect of troposcatter system realization, will corroborate our evaluation of the HOT LINE Project in section 2 of chapter 5. There we conclude that it is quite likely SADTC work on SHAPE's ACE-High forward scatter system was not of a fundamental scientific nature. Rather, it was a case of quite necessary support in engineering implementation.

History

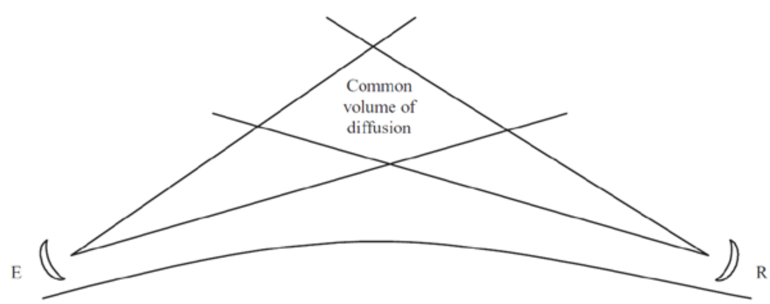

Figure 7: Two antenna cones and their scattering volume.

The field of tropospheric scattering matured with Booker's influential 1950 article applying the theory of scattering from a turbulent medium to radio waves and the troposphere[57]. This was during the mid-1950s however still a very new technology. Only a handful of experimental troposcatter systems (including a couple of unidirectional setups implemented by the Netherlands Postal Telephone & Telegraph Bureau[58]) and some American military installations including the POLEVAULT system which was part of the Mid-Canada Line[59], had been realized at the time the SADTC

[57] Booker and Gordon 1950
[58] Gunther 1966, 91-95
[59] McCamley 2013, unfortunately there are no page numbers in the books digital version but the most relevant information is found under the paragraph header "North American Air Defence Communication Systems" in chapter 2. As implied by its name the Mid-Canada Line was an early warning radar network situated in Canada. It formed three

worked on its HOT LINE system. With the advent of satellite communications however, significant development of the technology stalled during the sixties.

Basic Principles

The principle of forward scattering is that random irregularities or fast fluctuations in refractive index can scatter/reflect radio waves of the right frequency. As shown in figure 6, this scattering has to take place within the volume shared by the transmission and reception cones of the sending and receiving antenna respectively. This common volume of diffusion is limited in altitude to about 10km since above this height the tropopause begins, a region where the atmosphere's density and index of refraction suddenly changes. As the atmosphere then becomes too rarefied for sufficient scattering, this limits the effective range of troposcatter to the order of hundreds of kilometres[60]: much better than what could be achieved with line of sight communications systems, but not enough by a long shot for directly linking two regional headquarters such as Oslo and Paris. For this, scattering at a higher altitude, made possible by the technique of ionospheric scattering (cursorily described in the next section) was required.

Mention should be made that this technique is not very efficient; transmission path loss was quite severe running into the hundreds of decibels. Accordingly, very powerful transmitters and sensitive receivers are required when compared to Line-of-Sight systems; across Europe relics of ACE-High in the form old now-defunct dishes and antenna are still to be found. As mentioned however, beyond 120 miles the alternatives were simply not an option. Moreover, the relative path loss in decibels per mile was actually superior for these systems, as shown in figure 8.

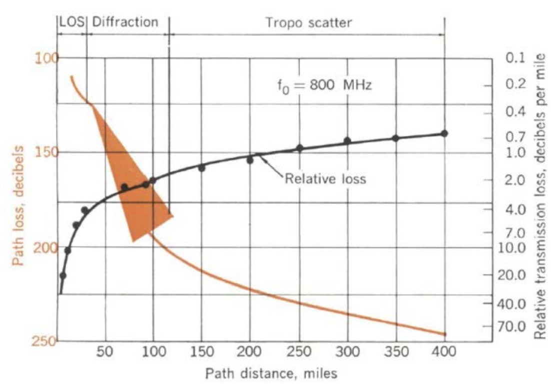

Figure 8: Absolute and Relative Path Loss, Source: Gunther 1966, Fig.9

concentric radar-cover circles together with the Pine Tree Line built a few years earlier further south and the Distant Early Warning (DEW) Line built a couple of years later much further to the north.

[60] Barue 2008, 291-292

Location Specificity

As might be expected of a technique based around the scattering off fluctuations in the atmosphere, the properties of the angle and efficiency of scattering achieved is very heavily dependent on the atmospheric specifics of the location where the system is to be implemented. These considerations furthermore have a bearing on the ideal frequency to be used for optimal data transmission bandwidth and reliability. Owing the immense complexity of underlying mechanisms, most of the optimization is based on measured datasets from similar climates. This is illustrated in figure 9 which shows the variation in climatic function which measures the modification needed to the median long-term transmission loss.[61]

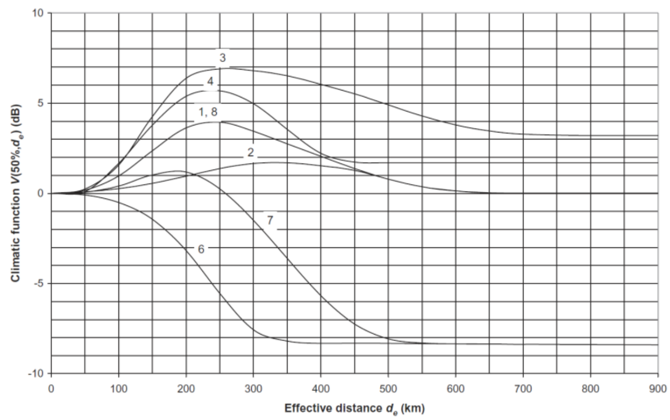

Figure 9: Climatic functions, Source: Barue 2008, Fig 4.10

Similar modifications are necessary on a seasonal basis, as with any given forward scatter hop the signal propagation characteristics fluctuate not only on very short timescales in the order of minutes but also on longer, more predictable and more or less seasonal timescales in the order of months.

As we can see from publications by researchers in SADTC employ, this sort of crucial information is exactly what was being gathered. Amplitude distributions both on short and long timescales are reported, and comparison is made between different operating frequencies and equipment for the specific case of Norway[62]. Thus, troposcatter was at the time a relatively novel and technologically advanced technique, developed and first operationally implemented in the US. However its very nature did not permit carbon copy export of the system, and required localization by some technically competent organization.

[61] Ibid, 304-307
[62] Knudtzon and Gudmandsen 1960

4.3.3.4 Ionospheric Scattering

This form of Over-the-Horizon communications allowed for much larger distances to be covered than troposcatter, typically between 700 and 1200 miles. With just 3 ionospheric hops, SHAPE HQ in Paris was connected to all its subordinate commands in Europe (Oslo, Naples, Izmir). This system doesn't utilize the refractive index differences caused by varying atmospheric density like troposcatter. Instead it uses the ionization of gases high in the atmosphere, appropriately called the ionosphere, to reflect microwaves.

A screen of free electrons will reflect incoming electromagnetic waves. However, due to the presence of many free ions the electrons aren't actually properly free and are somewhat shielded from one another. This gives rise to an electron distribution dependent on the density of 'free' electrons, which causes a certain maximum response frequency usually named the plasma frequency. Above this frequency, the ionosphere becomes transparent to electromagnetic radiation. The practical consequence is that ionospheric scattering operates on much lower frequencies than tropospheric scattering (as seen in figure 10), which is unfavourable for data transmission rates.

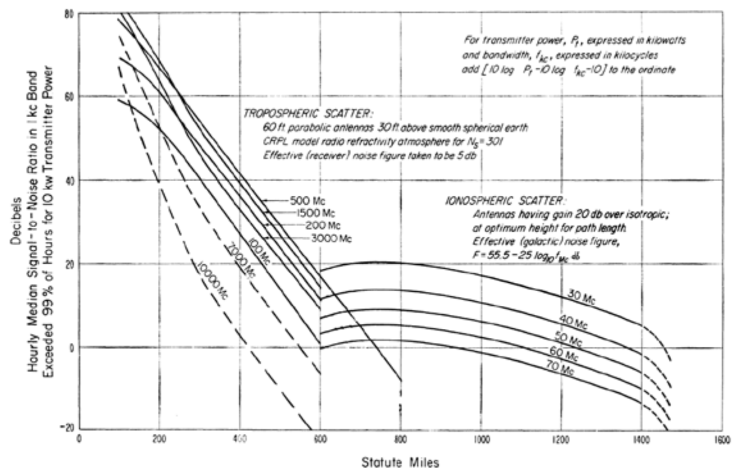

Figure 10: Signal-to-Noise ratios for tropo- & ionoscatter, Source: J.T. Advisory Committee 1960 , Fig 1-2

As can also be seen in the graph, it doesn't attain the high signal-to-noise ratio's that troposcatter typically enjoys, but it has a bigger range and is less sensitive to increased noise as the distance increases.[63]

As this technique is older than tropospheric scattering, it is very likely that most of the SADTC's work was in implementation and arranging subcontracting. Even moreso than with troposcatter, ionospheric scattering communications were obsoleted by satellites.

[63] Beynon and Williams 1978

Ionospheric scattering however, did find ongoing application by virtue of its use in incoherent scattering techniques for Over-the-Horizon radar.[64]

5 Work Undertaken and Role Fulfilled by the SADTC

In this chapter we consider the sort of projects undertaken within the SADTC to consider what sort of science and research was being conducted, and which role an international technical centre such as SADTC was able to fill in answering NATO's technical problems. In order to do this, we shall first take extensive stock of the structure and programme of work for SADTC in 1961 linking their work to the problems described in chapter 4. This first section will have something of an encyclopaedic nature as an attempt is made at an exhaustive overview of the main areas of activity, to offer the reader a good feel of SADTC's work. Next we shall in section 2 consider a few concrete projects undertaken, two in communications systems and one in air defence. Finally, we shall conclude that very little basic science or novel technological development was actually conducted at the SADTC, but that it mostly focused on problems of intra-alliance implementation of nationally developed systems, which involved many environmental factors and engineering challenges.

5.1 The SADTC Programme of Work

Unfortunately, most of the early programmes of work are to be found within currently inaccessible SHAPE and SADTC (now NATO Command & Control Information Agency) archives; whilst most of the material this thesis is concerned with is no longer classified in principle –both due to its age and the end of the Cold War– systems of classification within which they are embedded have in many instances not been updated to reflect this new reality. Furthermore organizations have not always been able to afford prioritizing Public Disclosure to the extent that practically enable the declassification and dissemination of the many decades' worth of unnecessarily restricted documents that exists.

However, a reasonable picture can be constructed from reports found in the UK National Archives, several released SHAPE documents, and programmes of work from 1960 onwards

[64] Ibid.

found in the NATO Archives (available from the point SADTC transferred to NATO control onwards).

The overview below is based on the general situation during 1960 and 1961 of which more detailed information was available. During the earliest years however, the SADTC consisted of a Forward Scatter Group (most directly identified with the Communications Group), a Radar Group, and an Active Defence Group[65] whose responsibilities were mostly absorbed into Systems Evaluation by 1961. These sections were all staffed internationally, though different sections tended to have varying predominant nationalities represented within them.

This overview of the work undertaken is structured according to the Groups extant in 1961.

5.1.1 Systems Evaluation Group

A division within SADTC focusing more on operational analysis than on hard science, engineering, and hardware. In the first 5 years of SADTC's operation, this division had existed but remained relatively unimportant as most of the Centre's big projects and focus lay in the realm of hardware-engineering. It did support efforts within NATO to draw up consistent definitions and performance review procedures for radar and communications systems of different origin however.

Some nations were chary about too heavy a focus on the technical side of evaluating systems, fearing competition. Furthermore, there was a general recognition that more than just engineering advice was required: SHAPE Staff Study had indicated a need for new concepts, implying operations and systems analysis.[66] Indeed, the initial Overhage study had conceived precisely such an analysis function in addition to engineering and implementation tasks.

Following recommendation by SACEUR to the NATO Council[67], the Council and then the CNR approved the proposal of installing Mr. E.C. Williams[68], an internationally renowned British operations analyst, as Director of the SADTC effective 1 October 1960. He proceeded to steer SADTC towards a greater focus on operations research and systems

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[65] UK Archives, Report made by Mr. P.S. Ziegler of his visit to the SADTC. 1 August 1957. T/225/2478.

[66] Dawson and Nicholson 1967, 574-575

[67] NATO, ACE, Recommendation to the North Atlantic Council for the Director and Deputy Director of SADTC. 1 July 1960. C-M(60)71

[68] NATO-SCNR, Summary Record of Joint Meeting of the Committee and SHAPE – Consultation Regarding Choice of Director and Deputy Director of the Centre. 2 September 1960. AC/165-R/1, paragraphs 121-122

analysis and evaluation, by 1961 this group was already the largest within SADTC, a reorientation which would persist in the years to follow; according to Dawson and Nicholson, this helped the Centre remain relevant to SHAPE.

Operations Research

Operations Research (OR) may be introduced thusly, according to one of its founders P.M.S. Blackett: "Many war operations involve considerations with which scientists are especially trained to compute, and in which serving officers are in general not trained. This is especially the case with all those aspects of operations into which probability considerations and the theory of error enters... the scientist can encourage numerical thinking on operational matters, and so can help avoid running the war by gusts of emotion..."[69] Blackett and his group of scientists played an important role in examining the British deployment of its radar systems in the Second World War.

In 1961, 18 SADTC scientists with an operational budget of 260,000 guilders (80k for computer rental, 180k for sub-contracts), were tasked with operational research applying its research methods to studying problems such as:

Survivability of ACE's retaliatory forces

As mentioned previously, this is the overall main aim of SHAPE's Air Defence programme. If deterrence is to be credible, NATO must be able to maintain its capability of effectively striking back in the case of major Soviet attack. This involves the integration of many smaller studies, to determine suitable postures to assume in various conditions of warning. Different mixtures of different passive defensive measures and offensive weapons may be employed in shaping and planning such postures.

Acquisition, transmission, and decision-making processes applied to tactical warning information

Studies considering the technical and operational means of obtaining, processing, and transmitting essential warning information when an attack occurs.

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[69] Baxter 1946

Command Control and Operating Procedures to be employed in the actual conduct of air battle

Air battle in NATO Europe is likely to differ in important aspects from past experience, implications for concept and philosophy of defence weapons systems are quantitatively evaluated.

Assessment of the methods for and likelihood of obtaining strategic warning and development of procedures for obtaining maximum advantages from it

The advantageous methods and operational procedures for SHAPE's mission were found to be extremely dependent on extent of strategic warning of attack. This group aimed to clarify the parameters of this interaction. Its work had obvious overlap with the intelligence field, but a more quantitative approach was desired here.

Systems Evaluation

Systems evaluation was something of an encyclopaedia service, tasked with compiling information on air defence systems such as SAM, Fighter-interceptors, and ballistic missile attack warning methods. The information was to be sourced at the NATO countries working in the respective fields. Furthermore, they're tasked with developing techniques for the comparative evaluation of defence weapons systems.

In 1961, 9 SADTC scientists with an operational budget of 363,000 guilders, were tasked with systems analysis.

Computation

This group was basically a supporting facility to all the other groups, providing numerics support where necessary.

During its early years however, SADTC did not have access to its own computer[70] and even when it finally acquired one as late as October 1958, it concerned a relatively slow LGP-30 computer which was not suitable for a fair deal of the numerical problems the Centre was confronted with.[71] As a result, the Centre remained dependent on outside computation

[70] Olle 2005, 312

[71] NATO-SCNR, Large-Scale Digital Computation Facilities for the SADTC. 14 December 1960. AC/165-D/6.

facilities for much of its analysis work, at great expense both directly and in man-hours (in many instances the best solution available were facilities in Norway (meaning quite a bit of travel time), since in the mid-50s, there were limited high-end computers available for rent in the Netherlands).

As this subgroup did useful work in support of many other groups who were all inconvenienced by delay, travel costs, and annual rental expenditures mounted in excess of 400000 guilders, concerted efforts were made to purchase a much more powerful computer in the near future for use in the Centre's work. Informal discussions had revealed that AGARD (discussed in Paragraph 6.1) would have use for access to such a facility as well. The costs would be quite significant however, between $1.3 and $3 million for a suitable transistorized machine, or $770,000 (not including installation costs) for an older IBM 704 system (utilizing vacuum tubes, there was a surplus as US organizations were replacing theirs with newer models) which would suffice for a number of years. The Committee of National Representatives ultimately favoured the latter solution, as such a system would be deliverable on shorter notice and constitute a much less hefty investment.[72]

Amongst the items of SADTC work utilizing computational assistance are fallout patterns, ballistic missile trajectories, Boolean algebra calculations, ionoscatter circuit performance analysis, and battle simulations. Of particular note is the European Air Battle Model (code name COMO) conceived at SADTC to tackle analytical problems in the realm of NATO air defence, for example in studying the simultaneous deployment of various systems such as Nike missiles, HAWK missiles, and manned interceptors. This had taken about 250 hours of computational time on the Ferranti Mercury in Oslo[73] during 1960 and was expected to take a lot of computational time in 1961 as well[74].

In 1961, 3 SADTC scientists were tasked with computation. The subgroup had no dedicated operational budget.

[72] NATO-SCNR, Summary Record of Joint Meeting of the Committee and SHAPE – Computation Facilities. 21 February 1961. AC/165-R/2, paragraphs 52-62
[73] Olle 2005, 312
[74] NATO-SCNR, Large-Scale Digital Computation Facilities for the SADTC. 14 December 1960. AC/165-D/6.

5.1.2 Communications Group

In a 1953 article on European Air Defence in Military Review it was pointed out, that air defence can be likened to an iceberg, in the sense that the visible part that you associate with it (such as jet airplanes, and later on the surface-to-air missiles (SAM)) constitutes only about 1/8 of the thing; the remainder, whilst hidden from view, is however also essential to the whole, and is in this analogy represented by radar chains, radar control and interception stations, communications, operations rooms, warning system, lines of supply, standard operating procedures, and so on.[75] It is to be considered against this context, that the SHAPE Air Defence Technical Centre actually did not do very much in the field of actual weapons development at all. Most work actually went into communications systems, data handling, systems planning and to a lesser extent radar and SAM-implementation studies. This corresponds to the problems discussed in section 4.3.3.

System feasibility

Systems and propagation investigations into the actual technical and operating capabilities on the ground, of the "ACE High" troposcatter system. The ACE High troposcatter needed to have actual capabilities determined, as its nodes were being realized and Standard Operating Procedures devised. One example of this is the study carried out by Knudtzon and Gudmandsen[76], both SADTC employees, carried out in 1957 on the first ACE High Troposcatter links realized under the header of Project HOT LINE (more details on this in section 5.2.1).

Another part of its work concerned a preliminary exploration into the feasibility of a 'novel ionoscatter system'. Furthermore transatlantic path oblique ionospheric sounding studies (basically measuring favourable paths for ionospheric communications in the Atlantic area) were continued.

In 1961, 9 SADTC scientists with an operational budget of 170,000 guilders and a capital budget of 325,000 guilders, were tasked with systems feasibility.

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[75] Gardner 1953, 97
[76] Knudtzon and Gudmandsen 1960

Ship/shore communications

Conducted work on shore installations for reliable communications with ships in the North Atlantic and Mediterranean, this was also an important factor in relation to Early Warning as ships are potentially valuable links in such a system. The implementation of many of these installations were the responsibility of the host nation, and SADTC acted as a consultant to these countries. Furthermore, ongoing studies were conducted into securing communications such that ship locations were not revealed. Finally, a number of tests with relevant equipment were carried out.

In 1961, 6 SADTC scientists with an operational budget of 20,000 guilders and a capital budget of 25,000 guilders, were tasked with ship/shore communications.

Communications analysis

Like system feasibility, this subgroup was mostly concerned with the operational and technical capabilities of ACE communications, however with a focus on analysis towards recommending means for improvement and deals with all the systems including telephone and telegraph circuits still comprising an important portion of ACE communications.

In practice it gathered information, studies of existing system capabilities, and carried out system planning.

In 1961, 6 SADTC scientists with an operational budget of 35,000 guilders and a capital budget of 55,000 guilders, were tasked with communications analysis.

5.1.3 Radar Group

ECCM techniques

Electronic Counter-Measures (ECM) such as measures to reduce an Aircraft's radar cross section and chaff generating false positives, presented a great threat to the ability of radar systems to accurately and reliably detect incoming threats, and as such facilitate early warning. Because of this, much importance was attached to monitoring ECM developments and their threat to NATO Europe. To this end, National developments in this area were reported to the Centre. "The application of this work is twofold: to influence the design of next-generation radars for use in NATO Europe, and to ensure the maximum continuing usefulness of existing and programmed radars."

In 1961, 3 SADTC scientists with an operational budget of 50,000 guilders and a capital budget of 500,000 guilders, were assigned to studying ECCM techniques.

<u>Detection and Warning</u>

Radar was increasingly important in warning systems as the range of ballistic missiles increased. The essential requirements were warning of launch and impact point precision. First, the optimum working frequencies for detection and tracking radars were to be established, as well as the orders of magnitude of the system parameters involved for missiles in the range of 500-600 km. Accounting for geographical differences between Europe and North America. This high priority study was carried out in cooperation with the Systems Evaluation Group, and relies on the release of relevant data from national sources. Furthermore, with regards to the low-level problem posed by for instance low flying aircrafts, the Radar Group focused on warning and target acquisition.

In 1961, 3 SADTC scientists with an operational budget of 30,000 guilders and a capital budget of 40,000 guilders, were tasked with detection and warning.

<u>NATO EW Radar System</u>

SHAPE tried to get the maximum bang for their buck, by making radar systems part of the EW chain double as support stations for aircraft control. "Several of the stations are planned to include control capability and improved ECOM capability in implementation of the long-range air defense plan. The group will assist SHAPE in specifying methods."

In 1961, 2 SADTC scientists with an operational budget of 2,000 guilders and a capital budget of 2,000 guilders, were tasked with consulting on the NATO Early Warning Radar System.

<u>Consultant services to SHAPE 1964 Air Defense Plan</u>

Whilst it had been decided this subgroup should render services, lack of clarity regarding its contribution stemmed from strong dependence on the result of then current studies. I.e. it was difficult to predict how the group would contribute to the implementation of the SHAPE 1964 Air Defense Plan.

In 1961, 2 SADTC scientists with an operational budget of 2,000 guilders and a capital budget of 2,000 guilders, were tasked with consulting on the SHAPE 1964 Long-Range Air Defence Plan.

5.1.4 Data Handling Group

Development of EW Transmission System

This regarded at this time the finalization of a final phase of testing and modifications of this part of a crucial SHAPE system. As the work is situated within the data handling group, we can conclude that the transmission system does not refer specifically to just troposcatter hops, but to the processing of data prior to and after transmission, as mentioned in section 4.3.2.

In 1961, 2 SADTC scientists with an operational budget of 30,000 guilders and a capital budget of 50,000 guilders, were tasked with development of the Early Warning Transmission System.

R&D into high-speed digital methods

This study examined the operational requirements for the data-handling system of the 1964 radar plan with regard to its technical implications. Also responsible for keeping SHAPE informed of developments in techniques and technologies which might find useful application against developing threats.

In 1961, 5 SADTC scientists with an operational budget of 250,000 guilders and a capital budget of 180,000 guilders, were tasked with conducting R&D into high-speed digital methods.

Compatibility - Co-ordination of systems development

Worked to establish agreed NATO standards for the passage of data within and between air defense systems. It accomplished this through setting up basic operational technical requirements and providing technical coordination between NATO and agencies responsible for national developments.

In 1961, 5 SADTC scientists with an operational budget of 150,000 guilders and a capital budget of 170,000 guilders, were tasked with Compatibility and Co-ordination of Systems Development.

Assessments of 2 ATAF Air Defense Systems

2 scientists were assigned to this project by SADTC to co-operate with the Systems Evaluation Group on this problem. No dedicated budget assigned.

5.1.5 Special Projects

Technical Assistance to SHAPE for the Implementation of the ACE Scatter Network

Following the successful delivery of the HOT LINE network, SADTC remained active consulting and assisting SHAPE with the implementation of the rest of the ACE High network.

6 scientists were assigned on behalf of SADTC to render advice, support, and troubleshooting services to SHAPE. Special financing obtained from NATO-infrastructure funds.

Consultant on Implementation of the STRIKFLTLANT/NEC Communications Project

4 SADTC scientists assigned, costs covered under special arrangements not within SADTC budget proper.

Remarks

As should become apparent from the above description, the SADTC was quite intensively involved in the analysis and implementation of SHAPE's Early Warning problem. Whilst there was definitely some work being done on Radar Technology and Data Handling, most of the Centre's energies were focused on the problem of communications within the European areas of NATO.

5.2 SADTC Projects

In this section, we study 3 SADTC projects: Firstly project HOT LINE, which regarded a 3-hop tropospheric scattering network across Norway, which was to become part of the much larger ACE-High Communications network implemented afterwards. Secondly, we take a look at project DOUBLE JUMP, which was a 2-hop ionospheric scattering system running across southern Europe from Turkey to France. Finally, we consider the role envisaged for SADTC in the realization of Surface-to-Air Missile (SAM) air defence measures. In all three of these case-studies, we shall find that the SADTC's role was mostly restricted to implementation, rather than development of new technology.

5.2.1 HOT LINE

SHAPE's Early Warning Radar plan was based on a draft submitted to it by SADTC[77] after acceptance it was implemented in part under SADTC coordination (HOT LINE), as detailed in the following paragraph.

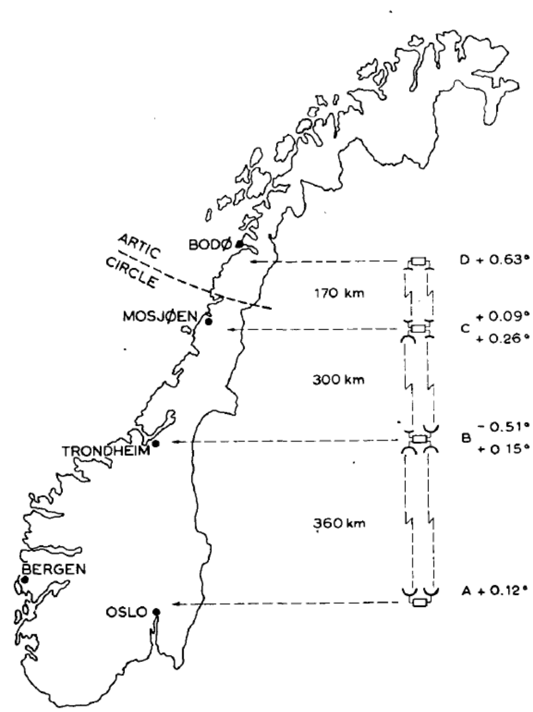

Figure 11: HOT LINE stations with hops ranging from 170 to 360 km. A future station is Bergen was also foreseen. Source: Knudtzon 1960

HOT LINE was a pilot project undertaken by the SHAPE Air Defence Technical Centre from 1956 to 1958 in order to gain experience with the implementation of tropospheric scatter communication systems, prior to its implementation across the entire SHAPE command area in Europe. It entailed a three-hop tropospheric scatter chain across Norway that linked from North to South, stations in Bodø, Mosjøen, Trondheim, and finally Oslo. After coordinating its implementation in cooperation with contractors International Standard Electric Corporation (electronics), the Norwegian Defence Research Establishment (construction works), and Hycon Eastern (consultancy), it conducted several tests to ascertain its characteristics and reliability.[78]

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[77] UK Archives, Report made by Mr. P.S. Ziegler of his visit to the SADTC. 1 August 1957. T/225/2478, paragraph 13
[78] Knudtzon and Gudmandsen 1960

After the successful installation and testing of this first portion of the ACE High Troposcatter network, the installation of the other 35-odd links in the system was left entirely up to external contractors, and implementation left up to the NATO Infrastructure Programme. SADTC did however continue to assist in its implementation as consultant and troubleshooter, with some personnel stationed at Paris for this purpose.

As is clear from its use of American expertise and other contractors, and its published measurements conducted on the HOT LINE systems, SADTC work mostly focused on implementation and adaptation of existing tropospheric scattering solutions, rather than development of entirely new concepts or technology.

5.2.2 DOUBLE JUMP

Project DOUBLE JUMP was approved mid-1956 with the goal of joining up SHAPE's headquarters in Paris with the subordinate headquarters in Naples and Izmir. It entailed a two-hop duplex ionospheric forward scatter system, and due to the utilization of ionospheric rather than tropospheric scattering a higher reliability was achieved, and longer distances could be spanned, allowing for direct links between subordinate headquarters (thus making the system far less vulnerable to disruption by sabotage or destruction of intermediate communication links).

Figure 12: Presentation of the DOUBLE JUMP project at SADTC

Work on project DOUBLE JUMP began February 1957 and was completed early in 1959, in cooperation Page Communications Engineers Incorporated, a subsidiary of Northrop under a $4.25 million contract.[79]

As is apparent from figure 13, similar to project HOT LINE, the SADTC-administered project only entailed part of the entire foreseen communications network, with the final link to AFNORTH HQ in Oslo to be completed at a slightly later date, presumably (no disclosed archive records were available) within the NATO Infrastructure Programme as was the case with the ACE High network.

[79] Conrad and Page 1959, 8

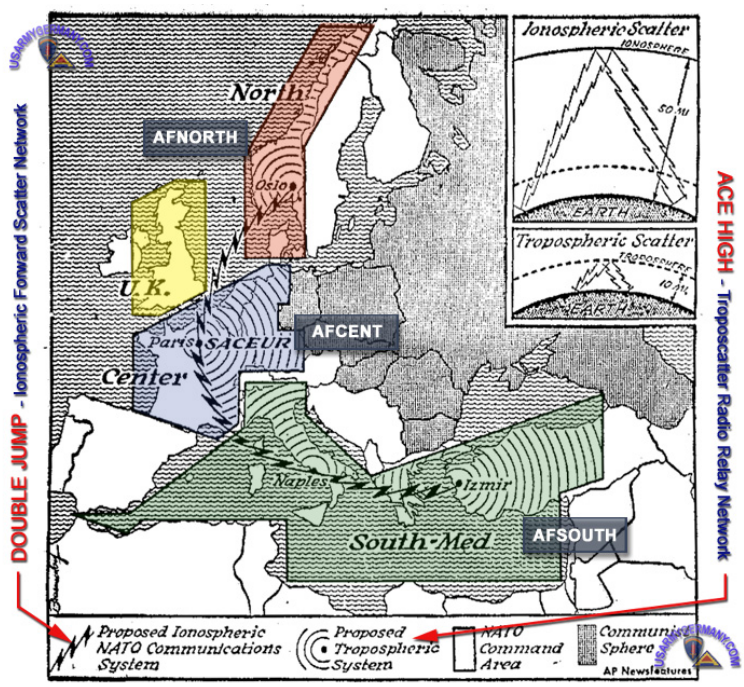

Figure 13: DOUBLE JUMP and ACE HIGH. Source: Stars & Stripes (22 April 1956)

Again, we find a similar pattern to the SADTC's role: Use of contractors and external expertise to coordinate the realization of the first test stations, in order that the centre might act as a consultant on future projects engaged in by SHAPE and NATO Infrastructure Programs directly.

5.2.3 Nike Hercules B Surface-to-Air Missiles

In 1956 the SADTC was instructed by SHAPE to examine surface-to-air missile implementation on the European theatre for air defence, with particular focus on Western Germany, which was a priority area at this time.[80] The short-term studies were to look at how such missiles might be appropriate to the control environment and infrastructure present in Western Germany; in other word it considered compatibility of these systems with the systems already present. This is indicative of a pattern where all the cutting edge technology was developed nationally in countries such as the US and the UK (this case regarded American NIKE missiles) whilst the SADTC was looked upon to facilitate its implementation in the final stages, which were technologically less interesting.

In this case, the request was made of SADTC without at the same time being able to furnish all the necessary information for conducting the study[81]. An example of national reluctance to provide information to international organizations on anything beyond a need-to-know basis.

5.3 SADTC: No place for pure science

The first central question of this thesis is what sort of basic research and science were conducted within NATO during the early Cold War. With regards to the SHAPE Air Defence Technical Centre we may conclude that the answer is: hardly any at all. The Centre

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[80] SHAPE, *Guided Missiles in Air Defence – Release of Information to SHAPE*, 31 January 1956, AG/6441/AD
[81] Ibid.

mostly limited itself to the final leg of development, analysis, doing extensive field testing under specific conditions and implementation, often by subcontracting. We shall argue how different sources and considerations confirm this picture: Firstly the programme of work and projects detailed earlier in this chapter (sections 5.1 & 5.2), secondly we consider the conclusions to be drawn from other secondary sources, and finally we consider the organization's original mission statement in this light. These will turn out to be fairly congruent.

Programme of Work

An overview of the activities undertaken in the SADTC's Programme of Work and our project examples leave little doubt as to the SADTC's role: Once the national big boys have produced their latest cutting edge systems, they will happily hand their new produce over for the unglamorous (if essential) task of implementation. Case in point: The development of Surface-to-Air Guided Missiles and the SADTC's role therein.

Estimation of Third Parties

After his 1957 visit to SADTC, Ziegler concluded that "very little original research" occured.[82] This was to be expected as most nations were not eager to share their top-end research results with the Centre. He does however conclude that the Centre is competent at the tasks it does carry out, makes itself useful through this work, and furthermore has special added value as it serves as a forum for information interchange between various nations and can due to the independent nature of RVO/TNO credibly act as an independent arbiter when comparing different competing technological systems for use within NATO.

Dawson and Nicholson in their 1967 paper conclude that the SADTC mainly limited itself to "hardware and engineering" work, and in the programme of work detailed above this sense is indeed palpable.

True to its Original Mission

However, suggesting that SADTC is somehow a failure for doing relatively little actual science would be wrong. It was always intended that way, the original Overhage report

[82] UK Archives, Report made by Mr. P.S. Ziegler of his visit to the SADTC. 1 August 1957. T/225/2478, paragraph 22

intended for a Technical Centre to furnish advice to SHAPE, which is exactly what SADTC did.

Moreover, if it were to get involved in actual science and important R&D, that would clear harm the interests of some member states. In a consensus-based alliance like NATO it was a given right from the start that only a non-threatening institution would be permitted to come into being. This illustrated clearly by SHAPE's letter about the procedure for release of information dated 30 January 1956, attempting to persuade countries to be more forthcoming with information towards SADTC, and making it clear that SADTC is in no way to be considered a threat to their national interests:

"The Air Defence Technical Centre has been designed to provide SHAPE with technical advice and assistance in the field of air defence for the benefit of the member nations of NATO. It is thus an agency of SHAPE. It does not have the resources to undertake original research, nor would it be economical for it to attempt to duplicate the scientific effort that is devoted to air defence by the individual nations. The function of the Centre is to give scientific and technical advice to SACEUR on the development and application of equipments and systems related to air defence in Europe."[83]

SADTC by its nature was always bound not to stand at the front lines of scientific research and development. It fulfilled a second tier support role in implementation and testing in the field whilst the large national Military-Industrial-Academic complexes of the US monopolized nearly all the interesting, high-profile and exciting work. Yet this does not diminish the value of or need for the Centre's work, the universal appreciation of its military necessity, the recognition of its indispensability to SHAPE, and the steady expansion of its programme of work and fields of competence in spite of misgivings in some treasuries and national interests sometimes dictating otherwise stand testament to this fact. To quote a SHAPE memorandum to NATO HQ regarding troposcatter implementation:

[83] SHAPE, letter on the subject of Release of Information to SADTC. 30 January 1956. AG/1250/AD. The letter describes the procedure SADTC follows in getting technical information on a need-to-know basis for every project it undertakes and continues: “Nations are asked to release information to SHAPE and to provide advice and guidance to the maximum possible extent to enable the Air Defence Technical Centre to fulfil its function adequately.”

"The Air Defense Technical Center is the only NATO agency which has the necessary scientific and engineering talent to supervise construction of the Forward Scatter System. It must, therefore, be the agency which selects the contractors and which places the contracts."[84]

6. NATO Science Committee: Science for the sake of Science

The NATO Science Committee (NSC) was quite a different beast from the SHAPE Air Defence Technical Centre. Whereas the latter was directly concerned with problems of a military nature, in particular those of SHAPE within the realm of air defence, the former was far more general in scope, focusing on the promotion of science within the Atlantic community in the broadest sense.[85]

This is down to differences in the situation and motivations leading to their respective establishment. As put forward in chapter 2, the NSC can be most directly considered to be a reaction to the USSR's successful launch of Sputnik in 1957. This event consolidated fears that the USSR was fast catching up to the West's technological and scientific advantage, and would soon be overtaking them. A different question called for a different answer, and the NATO Science Committee was conceived to meet this particular challenge.

In this chapter we first consider the role the NSC envisaged for itself, and find that in fact it wasn't too sure about this. Secondly, we consider some initiatives undertaken by the committee. The most important ones were, judged by how much funds were devoted to them, fellowships, summer schools, and research grants. Thirdly, we take a look at how unlike the SADTC, the NATO Science Committee actually tended to focus on the most general and pure science; and we evaluate that this priority was not only determined by ideology on the part of the committee's members, but also had some practical justification. Finally, we see how the tension between the direct interests of its paymaster, and the work it was actually conducting and supporting, led to a change in organizational structure and leadership, and the meaningful and relevant pursuit of basic science within a military alliance was always bound to be difficult.

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[84] SHAPE, Memorandum for General De Chasset: *Financing of the Forward Scatter System*, 1 March 1956
[85] NATO, Report of the Committee of Three on non-Military Cooperation in NATO. 10 January 1957. C-M(56)127.

6.1 Soul-searching: What role for NATO?

The first issue at hand for the initial committee was the simple question: "What do we actually do?" There seemed to be a lot of soul-searching and insecurity during early NATO Science Committee meetings as to the exact role NATO was to fulfil within the realm of science. In principle, it did not seem ideologically too farfetched to imagine an alliance of like-minded free democratic nations[86] promoting pure science in general. Nor could anyone object to aims such as bolstering communication and preventing duplication of work. But on the other hand, many of the most obvious ideas for facilitating science as a multilateral actor were already being considered at a 'more multilateral' level, with institutions that seemed more naturally placed to take on the job at hand, such as the OEEC[87][88]. At the same time, science could not be pursued purely for the sake of science, there had to be some added value from the perspective of the alliance and its individual member states.[89]

This contradiction was not really resolved clearly. Instead, the NSC simply proceeded with doing those things least controversial, and closest to the heart of its constituent members: supporting pure science in NATO Europe.

6.2 Patron of the Sciences: Following the Money

Eventually, a fairly safe and defensible option appeared to be measures to strengthen the scientific community between various NATO-nations. This was done by promoting the exchange of students and scholars through fellowship grants and facilitating their meeting at advanced study institutes (summer schools & conferences). This was intended to bring scientists and ideas from various nations into closer contact with one another, improving the chances of top talents moving to top centres of education and research irrespective of national borders. Furthermore, through so supporting science and education in a pure non-military form, NATO's prestige within the scientific elite would also be enhanced. Below is a

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[86] This aspect of NATO, enshrined in Article 2 of the Washington Treaty, had been re-emphasized by the Committee of Three's Report, the main internal impetus (Sputnik being the main external impetus) toward the NSC's establishment.

[87] Organisation for European Economic Co-operation. It was founded in 1948 to help administer the Marshall Plan, and reformed to the Organisation for Economic Co-operation and Development (OECD) in 1961, extending membership beyond Europe.

[88] NATO, Science Committee (afterwards, NSC), *Summary Record of the First Meeting on 26-28 March 1958*. 25 April 1958. AC/137-R/1, paragraph 15.

[89] NATO, Science Committee (afterwards, NSC), *Summary Record of the First Meeting on 26-28 March 1958*. 25 April 1958. AC/137-R/1

brief enumeration of the main initiatives, a feature all of them share is that there was very little pressure on participants to do anything related

Table 1: NATO Scientific Programme Expenditures (Thousands of Dollars)[90]

Programs	1959	1960	1961	1962	1963
Science fellowships	$1,000	$1,750	$2,500	$2,500	$2,500
Advanced study institutes	150	150	300	450	550
Research grants		500	800	780	835
Operational research				70	115
Human factors					
Total	$1,150	$2,400	$3,600	$3,800	$4,000

Programs	1964	1965	1966	1967
Science fellowships	$2,500	$2,500	$2,600	$2,600
Advanced study institutes	650	650	730	730
Research grants	735	735	750	745
Operational research	115	115	120	100
Human factors				25
Total	$4,000	$4,000	$4,200	$4,200

Fellowships

As evidenced in Table 1, most of the money went to these. By 1961, 765 fellowships were awarded, usually for a year. Generally, the fellows supported were between 21 and 35 years old and at the PhD or Postdoc level; over half of them were physicists, chemists, or engineers.[91]

This probably did not achieve too much, in terms of bolstering the magnitude of science within NATO. The reason is that it was clear that money contributed by the allies for this, was to be funnelled back to them in more or less the same proportion. Furthermore, in most cases the recipient nations were granted extensive autonomy over who to award these fellowships to.

[90] NSC, *NATO and Science*. 19 October 1965. AC/137-WP/22 ANNEX I
[91] Krige 2000, 96

What it did achieve however was some PR, as these fellowships and the work enabled by them would at least in name be attributable partially to NATO. Furthermore, some effort was made to support the scientifically weakest nations of the alliance such as Greece, to a larger-than-proportional extent, so it played some role in facilitating catch-up.

Advanced Study Institutes

Prime example is the annual conference in Les Houches, which still draws crowds of researchers every year. Such 'summer schools' were good for scientific exchange of ideas and enhancing the cohesion of the Atlantic scientific community, and promoting scientific exchange and therefore standards overall. The countries with the best-developed already existing scientific infrastructures were obviously best placed to make use of this programme, and most did in fact take place in France, Italy, the UK, and Germany, furthermore about half of the visitors came from the host country[92]. On the other hand, it may of course be argued that attending such conferences held relatively the greatest benefits for researchers in countries that lay furthest behind. But on the whole, the sense of solidarity apparent in the fellowship programme was absent in the summer school portion of the NSC's activities.

Research Grants

As can be seen from Table 1, the NSC did not start with research grants until the sixties, as a spin-off from the failed French proposal for the establishment of a Western Science Foundation. These research grants targeted fields suitable for international collaboration, such as oceanography, and favoured proposals by researchers in technically less-developed NATO member states.[93]

Overall, there was a strong focus on natural sciences, both in the Science Committee's constitution and the programmes and students afforded funds. This implies a preference for

[92] Ibid.
[93] Ibid., 100

fields of study in which the greatest operational shortages exist[94], and those most likely to produce the sort of research yielding direct military application in future.

6.3 Ideology vs Practical Concerns

These programmes answered the concern of Western scientific quality as exchange of information within a larger pool should be to the benefit of the scientific community in general and thereby enhance standards, particularly in those regions lagging behind, and the ideological wishes of the scientists appointed to the Science Committee. But it also arguably addressed to some limited degree the lack of technically qualified manpower within NATO by supporting students and research.

The NSC's direction was then, not determined solely by the ideology of basic science as acknowledged in the terms of reference it was endowed with shortly after Sputnik: "to increase the supply and improve the quality of scientific manpower and to ensure the optimum utilisation of this crucial resource and of scientific facilities in all fields … through co-operative measures where appropriate…"[95] Clearly, practical considerations of manpower played a role in promoting the cause of fundamental science and research. Furthermore, this programme addressed a need to bolster the alliance's prestige and cohesion following the USSR's post-Stalin policy of scientific outreach (detailed in chapter 2) to other nations, by profiling itself as more than a military organization.

However the scope and magnitude of these programmes (whilst not negligible) were not such that they could've had any more than a marginal effect, and they did not answer to the criterion of subsidiarity. There did not seem to be a particularly good reason for doing this on the supranational level of NATO, when great care was being taken to ensure most of the money went to students and researchers in approximately the same ratio as the funds were contributed. As mentioned already, in many instances, the Science Committee actually devolved its power over awarding fellowships to the relevant agencies within the countries concerned.

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[94] Trytten mentions the drop in the relative number of students graduating in the sciences, and stagnation of the share of engineers amongst college graduates within NATO countries, signalling that these are indeed the fields the NATO was concerned about.

[95] NSC, *Decisions Reached at the Ministerial Meeting in December 1957 and Terms of Reference for the Committee Approved by the Council.* 11 February 1958. AC/137-D/1 ANNEX, (Introductory Remarks to Terms of Reference)

6.4 Change of Course

In the early 60s therefore, NATO moved towards instituting a chairman of slightly less superlative scientific accomplishments, but with a more direct connection to defence research and industry. This did lead to some increase in the number of research grants awarded, and some more focus on subjects of a military nature, or in fields of military interest, however the main point of expenditure remained Fellowships and the Science Committee's budget did not increase appreciably during the remainder of the 60s and would not surpass $10 million.[96]

Even after changes in the structure and leadership of the Science Committee, it proved hard to move to conducting actual defence relevant research on the cutting edge within NATO. Just as was the case with the SADTC, national research interest trumped the potential benefits of "sharing and pooling" once again. As mentioned (in paraphrase) by UK NSC Representative Solly Zuckerman:

"To achieve any progress it was necessary to work through existing national institutions. As a member of the Science Committee he represented the United Kingdom government and also to a certain extent United Kingdom scientific opinion, including that of the universities, the research councils, the Royal Society, the Ministry of Defence and the Ministry of Supply. In order to bring about international co-operation, he was obliged to influence the views of those bodies: but it was not possible for him to persuade them that they should submit their research effort to the direction of the Science Committee. … it should not be unrealistic…"

In other words, there was some limited role to be played by the Science Committee, but this would always be subservient to the interests of national research industries. The NSC was therefore limited in what it could do, on one hand by the need for legitimacy in promoting science without arousing suspicion and bolstering the quality of scientists in Europe, and on the other hand by the fact that it was not a supranational body. The programme pursued by the Science Committee therefore best suited both its ideological character, and its practical aims within the constraints it had to obey.

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[96] Beer 1969

Limited Long-Term Relevance

As an interesting comparison, The Science Committee was established the year following Sputnik within a 15-member NATO context (though with a strong American impetus from the Jackson Report) and received an initial budget of around 1 million USD. Two other organisations were set up just after Sputnik in the US: The Defense Advanced Research Projects Agency (DARPA) which received an initial budget in 1959 of 500 million USD[97] (not inflation-adjusted) and the National Aeronautics and Space Administration (NASA) which by 1965 consumed roughly 5 billion USD per year[98].

So in the long run, NATO's Science Committee had somewhat limited relevance. Whilst it did serve to somewhat bolster NATO's image and supported some initiatives towards more scientific exchange, the margin by which it enhanced the level of research and intensity of scientific education within NATO Europe could not credibly be called very significant.

This lack of impact and further growth may be attributed to a failure by the Science Committee to deliver tangible added value and synergy for the alliance, however the political context is likely to have been of far greater significance in this apparent loss of interest: New intelligence had indicated that Soviet scientific prowess was not as formidable as had been feared, and the West had regained a great deal of its self-confidence concerning scientific knowledge and education. Lacking a sense of crisis and urgency, NATO allies reverted back to their old behaviour of protecting national interests, and the Science Committee simply utilized what manoeuvring space it had gained in its early years to achieve its ideological and practical aims the best it could.

7. NATO's further role in Science and R&D

So far we have considered what science was conducted within the SHAPE Air Defence Technical Centre and what activities were sponsored by the NATO Science Committee. But NATO's engagement in questions of a scientific and technical nature was by no means limited to these two instances, which are merely our case-studies. SADTC for instance, was

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[97] DARPA, DARPA Technology Transition: Executive Summary – DARPA Budget History. 1998, 12
[98] *NASA Budget History.* http://www.lpi.usra.edu/exploration/multimedia/NASABudgetHistory.pdf (*accessed: 14/07/14*)

established -in part- on the basis of precedent set by the Advisory Group for Aerospace Research and Development (AGARD) two years earlier, and even before that, NATO involved itself in many problems of a technical nature on an Ad Hoc basis through various Committees, Working Groups, and Groups of Experts.

Such involvement is by no means surprising, as the application of technical knowledge in military endeavours dates back as far as antiquity. However, owing to the ubiquitous nature of such military/technical entanglement, a full discussion thereof extends far beyond the scope of this thesis. We shall therefore limit ourselves to those instances where the alliance institutionalized programmes of science and technical R&D between 1949 and 1960. Besides SADTC, NSC, and the just mentioned AGARD, there was the Military Agency for Standardization (MAS), the Brussels Training Centre in Experimental Aerodynamics (TCEA), and the Supreme Allied Commander Atlantic (SACLANT) Anti-Submarine Warfare Research Centre (SAWREC).

We shall discuss these 4 institutions in turn in order to evaluate where SADTC and the NSC fit in the greater scheme of things before considering the general nature of institutionalized Science and R&D within NATO in chapters 8 and 9.

7.1 Advisory Group for Aerospace Research and Development (AGARD)

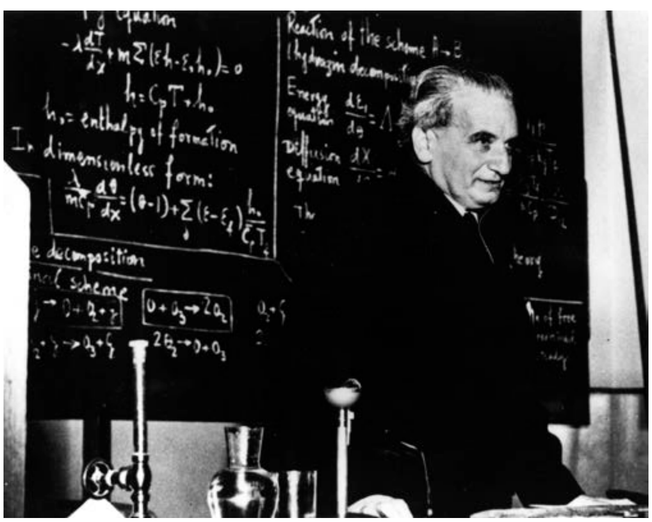

Figure 14: Dr. Theodore von Kármán

Dr von Kármán, a well-known Hungarian aeronautical scientist, was instrumental in the beginning of AGARD, which he himself described as follows:

"One day in April 1949, I read in the paper of the birth of NATO. Here was a small and simply administered group of nations bound together by the needs of defense. For my purpose it looked ideal. Why not use NATO as a pilot plant to test out the feasibility of scientific cooperation? I had concluded back in Volkenrode in 1945 that progress in technology was so swift that only a pool of nations could properly utilize scientific advances for mutual protection. With such an effort, it seemed to me, the international character of science could grow. After that, my ideas began to firm up. Why not set up for NATO a scientific advisory board similar to the Scientific Advisory Board of the US Air Force? Such a board could ensure the NATO countries that they would always have the best technology at their command."[99]

The Advisory Group for Aerospace Research and Development (AGARD) was established in 1952 as NATO's first scientific agency. The mission of AGARD was to unite NATO member states' leading experts in the fields of science and technology relating to aerospace to exchange information, improve cooperation, stimulate scientific advances, and provide scientific and technical advice and assistance in the field of (military) aerospace research and development for the common benefit of the NATO community. Under Von Kármán's leadership, a structure was developed in which scientists and engineers from NATO countries formed technical-scientific Panels that exchanged information, produced publications, organised meetings, carried out joint projects, organised study groups for the NATO Military Committee, and assisted each other in developing their research and development capacities. Under the Chairmanship of von Kármán, which lasted until 1963, AGARD formed several panels, instituted research committees, conducted long term scientific studies, and organised substantive conferences. Examples are the Combustion Panel, the Wind Tunnel and Model Testing Panel, the NATO Avionics Conference, and the Ionospheric Research Committee. Moreover, AGARD had close relationships with the NATO Military Committee and the NATO Science Committee.

Von Kármán's proposal to create AGARD was largely inspired by his experiences with the Scientific Advisory Board of the United States Air Force, which warmly supported the initiative.

7.2 Military Agency for Standardization (MAS)

Shortly after the formation of NATO, it was recognized that the co-ordinated development of policies, procedures and equipment of member nations held great potential for enhancing the interoperability of armed forces thereby bolstering military effectiveness and efficiency gains to be made, realizing economies for the individual members of the fledgling Alliance. As a result, the Military Office for Standardization (MAS) was established in London in January 1951 for the purpose of fostering the standardization of operational and

[99] Bliek 1999, 2-1

administrative practices and war material. Well-known are the hundreds of Standardization Agreements (STANAGs) made within NATO.

Whilst MAS was by no means a scientific organization, on some technical issues its responsibilities did overlap with those of the SADTC as it worked on aspects radar/electronics standardization.

7.3 Training Centre in Experimental Aerodynamics (TCEA)

The Training Center for Experimental Aerodynamics (TCEA) was established at Rhode-Saint-Genèse in Belgium in 1956 by agreement between the Belgian and United States governments, with the technical endorsement of AGARD. Like with the Science Committee, one of the chief concerns that led to the establishment of this institution was the serious shortage of technical manpower within NATO. The need to initiate this project without delay led the United States and Belgium to agree to finance the Centre bilaterally for a period of two years from October 1956.

7.4 SACLANT Anti-Submarine Warfare Research Centre (SASWREC)

"SACLANT Anti-Submarine Warfare Research Centre was established at La Spezia, Italy, in 1959. It is the only purely research laboratory operated by the North Atlantic Treaty Organization (NATO) and serves as the Command's principal adviser on undersea research. The essence of the Centre's work is to understand and predict the impact of the undersea environment on sonar performance and to investigate new sonar concepts, although other detection methods are not ignored. A large part of the Centre's work is the conduct of combined sea trials in physical oceanography and underwater acoustics."

It did however render SACLANT with advice on other matters as well, and thereby provided part of the inspiration for SADTC's reform into SHAPE TC.

Reviewing these 4 organizations, we find that most of their features are to some extent contained within the work and character of the SADTC and NSC. It should be noted however, that the Science Committee is clearly the odd one out, considering that its work had by far the least operational utility and the strongest ideological footing (in this respect, only AGARD is somewhat similar). We are therefore somewhat justified[100] in evaluating scientific efforts within NATO through the prism of our two case studies.

7.5 Defence Science within NATO: Multilateralism vs Coordinated Unipolarity

It cannot be reasonably maintained that on balance, military research & defence within the NATO countries become a significantly more multilateral enterprise throughout the fifties through NATO institutions. First off, national R&D budgets in the realm of defence dwarved collective spending on military science and research throughout this decade, and the size and scope of facilities such as the SADTC (which for years lacked even basic computing facilities) paled in comparison to national laboratories such as MIT's Lincoln Laboratory and AT&T's Bell Labs in the US, and counterparts in the UK and even in the Netherlands with Philips & Hollandsche Signaalapparaten (HAS).

Moreover, we find that in the nature of the work undertaken, national R&D laboratories and commonly funded collective technical centres were not treated on equal footing. When new Surface-to-Air Missile technology such as the US Nike missiles enter the last stages of development, SADTC is called upon to carry out studies on the implementation of these new weapons in the specific environmental conditions and the particular tactical constraints of the European theatre. All of actual development of these systems and cutting edge research is however kept within the confines national exponents of military industrial complexes. Just to get some detailed specifications of the systems whose implementation SHAPE institutions are asked to study, requires some effort on the part of SACEUR, as such information is not as a matter of course forthcoming. This says a lot about the hierarchy between national and multilateral R&D, and confirms Mr. Ziegler's 1957 observation that “very little original research is possible”.[101]

More generally, we see that nations are very keen to protect and where possible enhance their domestic research and related to that defence production. When the SADTC Committee of National Representatives proposes standardization of specifications of certain types of equipment, countries with a current vested interest in the production and export of such

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[100] We should remain cognizant however, as Bishop Butler preached: “Every thing is what it is, and not another thing.” Closer study of other institutions, in particular AGARD and SACLANT, would add more depth and nuance to our conclusions and might very well yield new insights.

[101] UK Archives, Report made by Mr. P.S. Ziegler of his visit to the SADTC. 1 August 1957. T/225/2478, paragraph 22

technology are quick to point out that such technology is so novel that having shared standards of performance may inhibit the still vibrant and possibly unpredictable innovations in this particular type of system.

Rather than true multilateralism then, we find a sort of multipolarity where every nation maintains and defends its own interests. On a large scale, the structure of cooperation may be taken to be roughly unipolar, owing the United States enormous preponderance in military R&D and subsequent production. Taking a closer look, we do however see that the UK and France also play a role of some significance in the development of new defence technology, and to a still lesser extent, the same goes for Italy, the Netherlands, and Norway; so that perhaps a more reasonable phrase than unipolarity would be lopsided[102] multipolarity. This means that all of the most interesting, challenging, and potentially valuable work tends to concentrate in these poles, first and foremost in the US; and much work is duplicated within the alliance. This perhaps not very surprising when considering that even within nations themselves, a fair deal of duplication of effort occurred, such as several different ballistic missiles programmes carried out by the US Army, US Air Force, and US Navy.

There is however very clear utility in the technical work and research carried out under NATO auspices. This is because there are certain challenges which clearly call for a concerted collective effort. Even whilst countries are eager to keep frontline technological development close at home, both from a political view of technological leadership and power, and from a more economical consideration of profitability in production and export to other allies.

Such collective problems include the drafting of plans for systems intended to span many nations, utilizing different technologies, work in improving interoperability, development and implementation of technology with its most direct and relevant application on an international basis within NATO context, and in acting as a more or less impartial arbiter setting common standards and terminology and comparing different rivalling systems.

An interesting observation, is that whereas the budget of technical centres such as AGARD, SADTC, and SASWREC tended to rise over the years, the Science Committee's budget quickly reached a plateau as shown in Chapter 5. This is most plausibly explained by the fact that whereas a great deal of the Science Committee's activities did not meet the subsidiarity

[102] Even compared to the expected rank-size distribution according to some power law.

principle and were of limited NATO-relevance, the activities of Technical Centres were such that they although they represented much less scientific merit, they were of actual value to the alliance, leading the SACEUR and national ministries of defence to label them military necessities on one hand, and the concrete programmes of work to gradually expand on the other.

8. The Dutch Factor

The Netherlands as a relatively small ally may be thought to be more or less obliged to follow the policies cooked up in the capitals of the large member states. This chapter gives some insight into the prevailing power relations, collective-action problems, and diplomatic bargaining dynamics view through the lens of NATO's Science and R&D programmes.

8.1 Distinguishing Factors

How did the Netherlands distinguish itself in the field of air defence related science and R&D within NATO? RVO/TNO and Hollandse Signaalapparaten (HSA) had proven competence in making gun laying systems and automated targeting, and possessed an effective 'TELEPLOT' system which attracted some attention[103].

Big companies such as Philips and medium-sized companies such as HSA represented the Dutch defence industry, which was relatively small but technically competent, leading in specific niches, and managed to translate such strengths to exports.

8.2 SADTC Location Choice

Why were RVO-TNO and The Netherlands chosen for the SHAPE Air Defence Technical Centre? This was not decided upon from the get-go: before settling on The Hague, other options such as Brussels, city, and city were considered and rejected. There is a number of reasons why this choice may have been made.

First of all, as the previous chapter illustrated the larger context shows NATO's spreading of new institutions over the allies in France (AGARD), Belgium (TCEA), London (MAS), Italy

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[103] Nooijen 2014, 27-28

(SASWREC), implying that it might have simply been The Netherlands' 'turn'. Certainly, it seems likely that US authorities felt that further concentration in France and Belgium was undesirable and there at this time no other NATO institutions on Dutch ground.

Secondly, proven competence and experience on the part of RVO-TNO in conducting defence research, and Dutch competence in the production of radar systems. The RVO/TNO's Physics Laboratory had actually independently developed a functioning radar system prior to the Second World War, and deployed one unit during the short aerial hostilities with Germany, though as might be expected never on a scale or level of sophistication comparable to the British efforts.[104] Furthermore, radar data transmission systems (TELEPLOT), and digital fire guidance systems show that relevant know-how was available in the Netherlands, and might be tapped into to permit SADTC to hit the ground running. Indeed, RVO/TNO was explicitly requested to partially staff SADTC's board, including its president Professor G.J. Sizoo who had garnered some international recognition[105] and was selected not by Dutch but by American decision makers. Furthermore, the Americans explicitly requested that the resources and facilities of RVO/TNO be made available to SADTC.[106] Some authors point out that Sizoo had paid a visit to American and Canadian research laboratories on behalf of RVO/TNO a few years prior to the announcement of SADTC, and may have played a pivotal role in attracting establishment of the Centre to the Netherlands.

Finally, and perhaps most importantly, the non-profit, quasi-independent, quasi-governmental nature of the Netherlands Defence Research Council appears to have been much to the liking of the USAF SAB's ideology and ties in with its earlier negative experience of too much direct military chain-of-command intervention in defence research[107]. According to Professor Sizoo this was at the time unique within Europe[108]. It was felt by the SADTC’s employees themselves that an independent scientific institution would render better research[109]. Within the Dutch governmental echelons, this was presumed to be

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[104] Harten, et al. 1974, 119-121
[105] Hoeneveld, *Dutch Physics and the early Cold War* 2014. (Unfinished PhD Thesis)
[106] NL Archives, Netherlands Ministry of War, *Bespreking betreffende het Air Defense Technical Center*. 4 December 1954. 2.13.142/668 – Verslag 481
[107] Redmond and Smith 2000, 23
[108] Jonker 1987, 21-22. An interview with professor Sizoo is contained within this document.
[109] Redmond and Smith 2000, 23

an important reason too, though confirmation thereof in US archives was not possible and remains desirable.

Whilst it is tempting to look for other hidden political explanations of the choice of settling on the Netherlands for the SADTC, the unique circumstance of RVO/TNO does actually hold some obvious merit apart from ideological conceptions of the ideal managerial circumstances for effective defence research. First off, the non-profit nature of the institution was in the words of one American official a good sell towards the American taxpayer[110]. Moreover, it placed it outside of the realm of many commercial companies whose interests were promoted within NATO-context by their countries as national champions. Finally, if the Centre was to render objective disinterested advice on matters of a politically sensitive nature such as integrated Air Defence, it would not be helpful for SADTC to be perceived as representing the interests of any one nation, even a relatively small nation such as the Netherlands. Indeed, the Centre was formally not only institutionally independent of the Dutch government, great diversity of nationality was to be found on its payroll, further bolstering its credentials as a representative independent advisor, in spite of not being a proper international organization as a necessary result of the conditions of its creation.

8.3 US hegemony vs Dutch wheeling and dealing

So was NATO-cooperation in the fields of science and R&D an affair mainly an American affair, initiated from Washington in support of the hegemon's interest and as an extension of foreign policy and international influence? The answer is a simple yes, this definitely appears to be the case.

However, as John Krige points out, hegemony is not necessarily a one-sided affair and can be coproduced[111]. A close examination the SADTC confirms to an important extent Krige's concept of consensual hegemony: The flip side to the MDAP funds and political coin spent on purchasing influence and protection of interests, is not a Western Europe lying prostrate and acquiescing to being utilized by the US however it saw fit. The fact that most of the dynamic did ultimately derive from across the Atlantic does not rule out consensual agreement or enthusiasm. Nor should it necessarily be an instance of a *quid pro quo*, where the US persuades or coerces its allies through linking up subscription to desired policies to

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[110] UK Archives, *Report made by Mr. P.S. Ziegler of his visit to the SADTC*. 1 August 1957. T/225/2478, paragraphs 3-6.
[111] Krige, American Hegemony 2006, 4-9

counter favours and things they want from them. There is a genuine shared interest in the defence of Western Europe and the reconstruction of its academic institutions and scientific relevance; a certain degree of reciprocal exchange and free-riding is a given at any time, however that does not explain why the British MoD overruled the objections from its Treasury to the SADTC, or the very senior scientific representatives delegated to the initial Science Committee: on the broader issues and direction of these organizations, there did exist broad agreement that both SADTC and NSC were the right institutions at the right time.

So it appears to be a case of mutually understood rational self-interest. Similar to the wider Marshall plan directly following WWII (an analogy not lost on Krige, obviously), authorities across the Atlantic understood that like economic development of Europe, full realization of its academic potential and mobilization thereof for the Atlantic cause was essential to the superpower's interests, and the eventual triumph of the West over the Soviet Bloc. In effect however, it was the smaller partners that were the most direct stakeholders and stood to gain proportionally most; America's technological lead over the other allies only served to enhance this effect. “Dutch entry into the US led arsenal of knowledge and contributed to the co-construction of the US hegemony in Europe”[112] was an important aim for the Dutch authority and major reason for investing along lines and patterns that would complement US efforts. Moreover, other small European countries such as Belgium, Norway, Sweden, and Switzerland did the same thing.[113]

This explains why on the whole American initiatives towards technical cooperation were met warmly, not just by the host countries of proposed research centres and programmes. Case in point is the reaction of the UK's MoD upon the US proposal for the establishment of SADTC with initial US funding, but with the clear intention of burden-sharing amongst all allies in the not-too-distant future: "We would take the view that [the US proposal to establish SADTC] is very fortunate, from our point of view [and its willingness to bear the expenditure for the first few years] seems [...] as much as anyone can ask." After Sizoo's visit

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[112] Hoeneveld and van Dongen 2013, 284
[113] Ibid.

to the US he presciently predicted the US was going to have a need for Europe and the 'European scientific mind'[114], he was not being gloomy.

9. Conclusions

On the whole, the practice of pure science within NATO remained constrained to a rather small scale. More money was made available for technical investigations and operational research into the solutions to concrete problems the alliance was faced with. This is completely understandable, but does to some extent dispel the idea that NATO was first and foremost motivated by some strong ideological commitment to the value of basic science and international cooperation. Whilst it is certainly true that most of the individuals and countries constituting the alliance ascribed real value and significance to this, and believed in these ideals, the fact remains that on the whole it was results that mattered and over the long-term priorities and financial support reflect this. A likely explanation is that it is the achievement of concrete, militarily non-controversial results is most likely to foster cooperation within an alliance of unanimity.

In that sense, the SADTC provides a clear case in point. Whilst there were certainly strong arguments in favour of more fundamental and cutting-edge research at this Technical Centre, such as the prevention of duplication of work within the alliance, member state's interests dictated that it should limit itself to such competences as would not compete with national military research industries. The airplanes, guided missiles, radar technologies and other high-profile technological state of the art products were to be developed in the US, the UK and France; SADTC should confine itself to compiling databases of the various systems' characteristics, supplying SHAPE with practical advice, and assisting in implementing the American systems in the countries of NATO Europe. In constraining itself within this limited role however, it did receive strong backing for concrete results delivered.

Even in the field of 'Pure Science' as represented by the NATO Science Committee, it is clear that pressing operational needs in terms of PR-requirements and the availability of scientifically trained personnel played a central role in the fellowships and institutes

[114] Hoeneveld, *Dutch Physics and the early Cold War* 2014. (Unfinished PhD Thesis)

supported. And even given this, it could not forever remain divorced from more practically relevant defence needs, as evidenced by the change in leadership in the early 60s. The pitfall it met on that road however, was that it was too general in its outlook to engage in applied scientific research without becoming a threat to national research interests. This accounts for the fact that it remained relatively ideological and maintained its support for students and scientific exchange reflects on one hand its relative irrelevance, and on the other the extent to which the lack personnel truly was pressing.

So Science and R&D in NATO consisted of one part operational expediency, one part American interests and influence, and a sprinkling of ideology. Technical activities actually conducted within NATO were more accurately typified as defence consultancy and engineering services than as pure science, as evidenced by our study of the SADTC. Pure science conducted by third parties was however promoted by NATO on a limited scale, but only due to temporary ideological fervour brought on by the shock of Sputnik, and mostly for the practical benefits of PR both toward the general public and to a lesser degree as an overture to potential technically skilled employees.

Small countries tried to find their own niche within this US-dominated topology, which was seemingly accommodated by NATO through the distribution of various technical centres amongst the different countries. Through this, relatively large influence on relatively small areas of research policy was afforded, whilst elsewhere such influence was negligible. The Netherlands had a big stake in work on air defence through the SADTC location choice, and its strong representation on its board. At the same time, the Dutch did not play a very significant role in the NSC's direction.

That this was tenable is owed mostly to the fact that on the whole however, interests with regards to the ultimate object of air defence and science within NATO did align. All allies had a stake in their collective security and prosperity, and were willing cooperate on those issues where they agreed such benefits would accrue to all. This included staying up-to-date with regards to air defence and basic science.

Acknowledgements

I would like to thank Professor Jeroen van Dongen and Friso Hoeneveld for valuable discussions, insightful tips, and their patient supervision. Furthermore my appreciation for the very helpful assistance rendered by the people at the NATO Archives, in particular Nicholas Roche, Nicholas Nguyen, Eudes Nouvelot, and Johannes Geurts for their time and great help in finding my way around the material in Brussels so graciously made available under the Public Disclosure programme.

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