

Military OR/SA in Germany since the 1960s

A Personal Recollection and Outlook

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Abstract: The paper describes the author's experience in German military OR/SA since its beginning the early 1960s to support of R&D and weapon systems procurement in the 1960s and 1970s and the analysis of defence concepts, including stable defence in support of conventional arms control in the 1970s and 1980s. In the 1990s, attention shifted to questions related to restructuring of military forces after the end of the Cold War and, with a view to the emerging new security environment, attempts at defence reform in Germany at the end of the 1990s and early 2000s including capability-based planning accounting for uncertainty regarding the mission environment. In conclusion, the re-orientation of military OR since the turn of the century to support defence transformation is discussed.

1. Origins of German Military OR

The origins of German Military Operational Research or Operations Research, as it was called following the American terminology, date back to the late 1950s after the Federal Republic of Germany (FRG) had begun to re-build military forces and joined NATO in 1955. Instrumental in developing Germany's initial military OR capability was a team of eight OR analysts of the U.S. aircraft company Northrop that was selected by the German Ministry of Defence to investigate, together with a team of engineers from three German aircraft companies, the suitability of various VTOL aircraft designs for operations from dispersed sites to improve ground survivability of air assets under threat of nuclear attacks.¹ The Northrop team led by Jim Taylor arrived in late 1961 and established offices in the facilities of the newly founded IABG² in Ottobrunn located in close neighbourhood to the German Air Force Technical College where I served at that time as a deputy squadron leader and instructor. I met Jim and some of his team in the summer of 1962 at the college when, as part

¹ The three companies were Bölkow, Messerschmitt and Heinkel which had joined forces in the late 50s to build up an OR capability for EWR (Entwicklungsring Süd), their joint aircraft design and development group. It was Ludwig Bölkow, the founder of the company named after him, who recommended to MoD that this group be awarded a contract to evaluate the operational effectiveness of the VTOL prototype VJ 101 developed by EWR. However, MoD was sceptical about the OR expertise of EWR's young team and hired the experienced Northrop team to lead the VTOL evaluation and train EWR analysts on the job. The reader is referred to Fischer (1996) for a detailed account of the early history of the FRG's military OR organization.

² Industrieanlagen-Betriebsgesellschaft (IABG) was founded in 1961 as a non-for profit organisation owned by MoD to operate central testing facilities for the German aerospace industry working on government-funded development contracts.

of their contract, they gave lectures on Operations Research. I was immediately attracted by the quantitative approach to operational problems and succeeded in getting a temporary duty assignment to the Operations Research Group (ORG) as the German-American team was officially called. When my tour of active duty with the German Air Force ended in December 1963 I joined ORG as a civilian analyst. At that time the group had become part of IABG where it was supported by a Military Advisory Group provided by the Office for Studies and Exercises of the Bundeswehr. It grew from some 20 analysts in 1963 to a maximum of more than 1200 in 1978. It was organized in separate subgroups providing decision support to the staffs of the three service branches, the joint staff and the armaments division off MoD.³ For more than 30 years IABG's study division was essentially MoD's in-house operational and technical analysis capability until the company was privatized in 1993. Today, operating in 12 German and European locations the privatized IABG comprises a staff of about 1000 scientists and engineers. In competition with other contractors about 350 of them still work for the German MoD on defence and security problems. The former military advisory group is now one of three divisions of the Center for Transformation of the Bundeswehr.⁴

2. Phases of German Military Operations Research / Systems Analysis

In retrospect, the evolution of military OR/SA in Germany may be characterized roughly by four major overlapping phases that reflect the increasing scope of OR analyses during the Cold War and the search for new issues and approaches some time after it had ended. In the initial phase (1960s – 1970s) the emphasis was on weapon system cost effectiveness studies, followed by theatre-level defence system improvement studies in the second phase (1970s – 1990s), and stability analyses and defence reform studies in the third phase (1990s – 2000s). The current fourth phase (since around 2002) is characterized by the development of approaches and analyses in support of force transformation to make the Bundeswehr fit for coping with the challenges of the 21st century

2.1 Weapons System-oriented OR/SA (1960s-1970s)

The first project I worked on during my temporary duty assignment to ORG in 1962 was typical for the problems of the early 1960s. The question asked by the German Air Force was about cost effective options to improve the range and ground survivability the F 104G Starfighter. Realizing that improving aircraft ground survivability in a nuclear environment required widely dispersed basing lead to the conclusion that VTOL designs might offer better options than equipping the F104 with auxiliary rocket boosters for launch from dispersed racks.⁵

³ I left IABG in 1975 when I was appointed Professor of Operations Research – and later Applied Systems Science – at the Universität der Bundeswehr München (University of the German Armed Forces Munich) founded in 1973. There, together with three colleagues of the computer science department I formed the Institute of Applied Systems Science and Operations Research (IASFOR) where interdisciplinary research was performed on modelling conflict and analyzing longer-term defence and security issues beyond the immediate interests of decision makers in MoD.

⁴ The three division are: 1) *Transformation* responsible for observing and analyzing trends relevant for the adaptation of the Bundeswehr's capability profile; 2) *Concept Development and Experimentation (CD&E)* responsible for the development of models and procedures to support the development of innovative concepts of operation and their experimental validation; 3) *OR and M&S* responsible for providing analytical support to decision makers in MoD and the field forces as well simulations for training purposes.

⁵ Several V/STOL prototypes were under development in Germany at that time: VJ 101 by EWR (Messerschmitt-Bölkow-Blohm); VAK 191 by VFW-Fokker; Do 31 by Dornier.

To support the definition of efficient requirements for and the assessment of the effectiveness of weapon system designs a series of mathematical model developments were initiated by ORG during the 1960s. The first one was the “Requirements Model” developed by the original German-American ORG to assess the operational requirements for VTOL combat aircraft. Building on this model and the experience gained during its application study, the “US/FRG V/STOL Tactical Fighter Effectiveness Model” was developed by ORG in cooperation with RAND and the OR department of the Aeronautical Systems Division of the USAF Systems Command (Frick et al, 1969)⁶ It was used for the assessment of a series of conceptual design options submitted to the joint German-American Systems Project Office by each of three German-American aeronautical industrial consortia. In addition to aircraft performance and weapons data, the input variables related to mission requirements in terms of a typical target array to be neutralized within a certain time span, the enemy’s counter-air threat, air defence deployments of both sides, and one’s own ground support capability and associated sortie generation rates. The relative cost effectiveness of options was determined in a straightforward manner by comparing life cycle cost associated with the minimal number of aircraft required in each case to fulfil the mission requirements. The minimal number was estimated by means of an optimization algorithm trading range and/or payload versus altitude profiles for improving mission survivability.

An advanced version of the Tactical Fighter Effectiveness model was used to support the definition of requirements for a new tactical fighter (NKF) by the German Air Force after the US/FRG V/STOL project was cancelled mainly because of the change of NATO’s defence concept in 1967 from *Massive Retaliation* to *Flexible Response*. The respective study was the basis of Germany’s initial position in the multinational negotiations on requirements for the common development of a combat aircraft to succeed the F 104G.⁷

In addition to the weapon system effectiveness and life cycle cost models, ORG developed simulation models for investigating the performance of logistic support such as, for example, the maintenance and service organization of an air wing responsible for generating mission ready aircraft under varying deployment concepts. A modification of this model was used on a routine basis by the air wings’ planning sections to plan and re-plan, if necessary, the annual operational activity schedules for meeting the NATO training standards for air crews. ORG also supported the organization and evaluation of field experiments (e.g. search for and detection of ground targets by airborne platforms) and operational tests (e.g. Cat III tests of the F 104G and G 91) to develop and update the empirical data base for weapon and support system modelling (Fischer, 1968).

Following air OR, analogous groups were added to ORG in the mid-1960s to support the German Navy and Army.⁸ With help from the Royal Armament Research and Development Establishment (RARDE) at Ford Halstead, the Army OR subgroup developed ORG’s first man-in-the-loop simulation model FORKS (*Forschungskriegsspiel*), a brigade level war game

⁶ Frick/Huber/Niemeyer/Rath: Tactical Fighter Effectiveness Model. Report ASB69-9, ASD-USAFSC, 1969

⁷ A respective memorandum was signed in 1968 by Belgium, Canada, FRG, Netherlands, Italy and UK. Shortly thereafter Belgium Canada and Netherlands ended their cooperation because they regarded the various national requirements as incompatible. Italy and UK continued to work on a design study that was presented on 1 May 1969. One year later design specifications were agreed upon between Germany, Italy and UK under the designation MRCA (Multi Role Combat Aircraft) later named Panavia 200 *Tornado*. I remember well the presentations of the mutual OR requirements studies and the discussions in the bilateral FRG-UK air staff talks in 1968/1969.

⁸The original ORG supporting the MoD’s air staff became ORL (L for *Luft* = Air) when the OR group of Bölkow K.G. was attached to ORG as ORM (M for *Marine* = Navy) in 1963 to support the German Navy Staff. ORG’s third subgroup ORH (H for *Heer* = Army) was established 1966.

played on a terrain board. FORKS served as a research tool to develop assessment rules and models to assist the umpires in gaming experiments and eventually replacing them in the computerized brigade-level war game COFORKS that was extensively used for developing the data base for the development of closed (without man-in-the-loop) event-oriented theatre level simulation models such as TREND (see Rehm, 1975 and Wiegand, 1975).

Together with the tactical fighter effectiveness and air defence models, COFORKS was integrated into the air-land war gaming system OPS (*OR Planspielsystem*) that was first tested in a large scale staff exercise in 1970 (*Bundeswehrplaniübung 1970*) to demonstrate the use of OR/SA approaches for supporting the assessment of weapon systems and force capabilities for forward defence in Central Europe.

2.2 Defence System-oriented OR/SA (1970s-1990s)

In addition to supporting force structure planning, increasing the scope of OR analyses beyond weapon and support systems to include the entire defence system in NATO's central region (AFCENT) was driven to a large measure by analytical support requirements in the context of 1) the Mutual Balanced Force Reduction (MBFR) negotiations between NATO and the Warsaw Pact which began in 1973 and 2) the Long Term Defence Programme (LTDP) that the NATO defence ministers had agreed on in 1977 (see Huber and Schmidt, 2000a).

The ultimate goal of the MBFR negotiations was an agreement on the reduction and control of conventional weapons and forces, on the territories of the FRG and the BENELUX countries (Belgium, Netherlands and Luxemburg) on NATO' side and GDR, CSSR and Poland on the WP side, that would not diminish the security of either side. Motivated by the apparent intransigency of the WP in MBFR-negotiations on one hand and de-emphasized defence spending by European NATO partners in the wake of détente on the other, the LTDP called for a real three-percent increase of the annual defence expenditures of all NATO members to improve NATO's defence capability to a level sufficient for credibly deterring WP attacks against NATO territory. In other words, the question facing analysts in case of MBFR was which mutual force reduction packages would not adversely affect either side's security in Central Europe, and in case of LTDP how to invest the annual three percent budget increase in order to maximize the return in terms of deterrent capability (buzz word: spending more and more wisely).

Both questions implied optimization problems that could, however, not easily be cast in sufficiently abstract terms amenable to mathematical optimization as they were characterized by large numbers of interdependent variables. The abstractions to be made in this case are illustrated by the macro-model of tactical air operations (MAMOTC) proposed by Huber (1980a) to assist air armaments planners in reducing the large number number of tactical air system mix options for subsequent investigations by means of war games.⁹ Thus, IABG's systems studies division¹⁰ intensified efforts to improve its combat analysis capability by

⁹ MAMOTAC involved a multi-stage analytical game to determine defensive and offensive tactical air allocations to be made by two antagonistic parties to maximize their relative capabilities to support the ground battle in the early stages of a war between them.

¹⁰ Formed during IABG's reorganization in 1972, the Systems Studies Division (SO) was one of five divisions of the newly established studies directorate. Three of them (SO, SZ, SV) integrated ORG expertise so that eliminate functional redundancies that had resulted from the service-oriented organization of ORG were eliminated. SO included the combat operations related OR expertise of the Army, Air Force, and Navy subgroups of ORG as well as the newly formed joint war gaming centre (see Huber, 1980b; Fischer, 1996, p. 21). SZ included OR-expertise related to C2, intelligence, and defence economics, SV to logistics, medical support and planning systems. I became the first director of SO, a position I held until I was appointment to the OR-chair (later

developing a hierarchical war gaming approach for numerical experimentation on different levels of aggregation with lower level games providing inputs to the higher level ones. The idea was to capture the realism of high resolution combat models at the lower levels while retaining the capability of low resolution models for processing large numbers of mutual force options that might be proposed by MBFR negotiators and NATO force planners respectively. This hierarchical game system consisted of COFORKS at the lowest (brigade) level, the integrated ground/air war game KORA (corps level) level, and the integrated theatre-level ground/air war game RELACS (Niemeyer, 1975).¹¹ Supplementing the war games were analytical models developed to support the evaluation of the games to establish trends and provide inputs for optimization models designed to support, for example, equipment and personnel planning for military units (Wiegand, 1975 and Schmitz, 1984).

In the 1980s these war gaming systems of IABG were gradually replaced by three families of more responsive and enriched simulation systems than could be operated without men-in-the-loop (SIRA, HORUS, JOANA) involving more than 13 major new model developments for simulating combat and support operations as well as battle field command and control (Hofmann et al., 2002).

An interesting application of theatre-level models was the so-called “90 Day Study”, a trilateral effort in which the three participating nations (US, UK, FRG) used different simulation systems¹² to test, based on jointly adjusted inputs and a commonly agreed scenario, the hypothesis forwarded by the United States that NATO forces in Central Europe were able to fight delaying battles by conventional means for about 90 days before having to consider a nuclear response. Common scenario and inputs notwithstanding, the results of the experiments supported the different views of the three nations about the duration of the conventional phase of a defence battle in the central region. In searching for an explanation, the analysis of the gaming models used by the three nations revealed that they were built on the assumption that tactical doctrine and command and control (C2) were essentially uniform and identical to their own across the layer-cake national defence sectors across the central region. However, in reality both doctrine and C2 were sufficiently different to cause concern about inconsistencies that these assumptions may imply for planning to conduct forward defence in neighbouring sectors.

Toward the end of the 1970s, the Institute of Applied Systems and Operations Research (IASFOR) at the University of the Bundeswehr Munich founded in 1973 began to develop both analytical and simulation models for the evaluation of alternative defence options – as proposed, for example by retired military officers sympathetic to the peace movement at the time (see Huber et al, 1981 and Huber, 1986) – and for investigating conditions of military stability in the sense that conventional forces of opposed parties are sufficient to meet each parties’ security requirements in case of being threatened by the other party (Huber, 1990 and 1991; Hofmann, 1991). Among others, this work was supported by a sizeable research grant awarded by the VW Foundation in 1989 to analyze aspects of conventional military stability in Central Europe and develop models for the quantitative assessment of stability conditions.¹³ The respective models were the basis for Germany’s major contribution to

Applied Systems Science) at the Computer Science Department of the University of the Bundeswehr Munich in 1975.

¹¹ The entities controlled by players were platoons in COFORKS; battalions/companies/platoons (optional) and operational air units in KORA; divisions/brigades and operational air units in RELACS

¹² To my recollection an advanced version of IDAGAM was used by the US (see Bracken et al, 1975), the NATO Deployment Model by UK (Dare and Thomas, 1975), and TREND by FRG (Wiegand, 1975).

¹³ The VW project pursued an interdisciplinary approach involving five research packages: 1) Definition of bipolar military stability and development of a mathematical model linking the variables affecting stability; 2)

NATO-DRG Panel 7 Research Study Group 18 on “Stable Defence” in the early 1990s which involved 1) the development of a mathematical framework for analyzing regional military stability that inter-relates intentions, risk attitudes, and military power including operational doctrines and 2) the conduct of combat simulation experiments for testing hypotheses on stabilizing effects favouring the defender more than the attacker (Christensen, 1995 and Hofmann et al., 1995).

2.3 Stability and Defence Reform-oriented OR/SA (1990s-2000s)

With the fall of the Berlin wall (9 Nov 1989) and the collapse of the Soviet Union (26 Dec 1991) most of the problems on the agenda of German military OR support had disappeared. In fact, it was my impression that over a period of several years its customers in the MoD were somewhat uncertain about future threats and emerging new problems that required analysis support.¹⁴ Thus, devoid of analysis problems MoD tried to save its OR/SA capabilities by tasking its OR institutions to document the numerous models developed during the Cold War period and convert some of them into training simulators for military staffs and war fighters, and assess their potential for adaptation to address the new operational tasks and missions that began to emerge in the mid-1990s in course of the conflicts in the Balkans. Thus, for almost one decade military OR in Germany was focussed primarily on consolidating its modelling and simulation (M&S) capabilities and developing concepts for their validation, verification and accreditation (VV&A) than on operational analysis in support defence decision makers (Hofmann et al., 2002). Only after MoD decided in 2002 to support military transformation did military OR/SA return to the analysis stage.

The situation at IASFOR as an academic institution was different. Recognizing apparent trends in the post-Cold War defence and security landscape we focused on developing quantitative models to support analysis in three areas: 1) post-Cold War European security and NATO enlargement; 2) restructuring of military forces in Europe; 3) impact of strategic uncertainty in military force planning.

2.3.1 Post-Cold War Stability and NATO Enlargement

In the second half of the 1990s IASFOR’s stability models provided the analytical framework for addressing post-Cold War security issues and both Russian and Western concerns about implications of NATO enlargement.

At the core of our stability models was the so-called *Stable Regional Force Ratio* (SRFR) concept defined in terms of the regional combat power ratio between a potential attacker and

Developing a model for stochastic combat simulation experiments to establish break-through probability distributions as a function of the combat power/force ratios in the attacker’s main thrust sectors; 3) Defence funding and criteria for fair burden sharing in an alliance; 4) Development of mathematical models for the verification of arms control and disarmament treaties; 5) Development and testing of a concept for computer-assisted crisis management gaming (Huber, 2002). The kick-off meeting for the VW project was organized in form of an international symposium held 10-13 October 1989 for taking stock of international efforts on modelling military stability and finding international partners for research cooperation. This symposium was remarkable for three reasons: 1) First time participation of scientists from the Soviet Union and WP countries; 2) Key note speech given by Dr. Richard von Weizsäcker, then President of FRG; 3) Taking place during the week when GDR celebrated its 40th anniversary about two months before the Berlin wall came down on 9 November 1989 (Huber, 1990).

¹⁴ In fact, I was told in 1998 that “the times of quantitative analysis in support of security and defence policy issues had passed some years ago” when asking for funding IASFOR’s participation in NATO-Russia talks on NATO enlargement that Chris Donnelly, the special advisor to the NATO Secretary General on Russia, had asked for because of our familiarity with the respective Russian models

its victim at which the defender's security requirements were met given the military forces available to both sides and their operational concepts. Security requirements were defined in terms of two criteria: 1) The *defence success criterion* defined in terms of the probability that the defender can thwart the attack given the operational concepts of both the attacker and defender; 2) The *defence sufficiency criterion* defined in terms of the probability that the combat power that the defender can bring to bear is sufficient to keep the probability for a successful attack in the eyes of the potential aggressor below the threshold at which he would consider attacking. Thus the defender's required regional combat power ratio depends on the defender's assessment of the attacker's risk aversion (Huber and Friedrich, 1998).

In addition to the assessment of the stability implications of various hypothetical alliances of former WP countries (Huber and Schindler, 1993), we used our stability model GEFRAM (Generalized Force Ratio Model) to reproduce the results of Russian studies on the effects of NATO enlargement (by Poland, Czech Republic, Slovakia, Hungary) on Russian security conducted by Vitaly Tsygichko (1995 and 1996) on the basis of his *Model of Defense Sufficiency* applied to what Russia considered as sectors of potential risk along the perimeter of its borders. While supporting the general trend of his model analysis, the results obtained from GEFRAM using Russian threat and damage estimates¹⁵ did only partially support his findings. In particular we found that his defence sufficiency criterion was met only if Russian forces were able to muster a sizeable superiority of combat power in the sectors of potential risk even if the threat probability was rather low (e.g. < 0.1). This compared to what we had defined as the *defence success criterion* as opposed to our *defence sufficiency criterion*. Contrary to Tygichko's results showing that in the long term (2005-2010) Russia's degree of security would fall below its requirements in many sectors regardless of the terms of NATO enlargement, the GEFRAM results showed that this would nowhere be the case if NATO enlargement would follow the terms of the Russia-NATO Founding Act (Huber and Friedrich, 1998). From the results of a follow-on study we concluded that if Russia adopted our defence sufficiency criterion commensurate with its traditional low military risk aversion, of attacking only if the success probability was > 0.9 , it could considerably downsize its conventional military defence forces if it were to redeploy them appropriately and improve both their strategic and operational mobility for a responsive reinforcement of local forces raised in the sectors of potential risk in case of an imminent threat (Huber et al., 1999).

Opposition to NATO enlargement was not only voiced by Russia, but also in some NATO countries arguing primarily on grounds of the projected costs to NATO associated with adding new members from the Central European region to the Alliance. The respective costs for a basic option (minimum requirement for integration of the four new members into the Alliance) ranged between 60 billion US\$ over a 15 year period estimated by RAND (Asmus et al., 1996) and the Congressional Budget Office (CBO, 1997) and 13 billion by the Polish MoD (Firley and Wieczorek, 1996). The costs for building up a forward presence much like in Germany during the Cold war were estimated to exceed 125 billion US\$. The U.S. estimates were based on the assumption that the new members do both modernize their forces to meet NATO standards and preserve their manpower levels.

In contrast, recalculating the data showed that enlargement would not involve any additional costs to the Alliance if one were to assume that 1) enlargement need not increase NATO's

¹⁵ Damage estimates – generated on the basis of combat simulation experiments by means of the (systems dynamics-type) *Model of Strategic Operations* of the Russian general staff – were provided by Tsygichko in terms of the degree of potential damage measured as the probability that Russia would suffer unacceptable (vital) damage if attacked by the combined military forces of the neighbouring countries in each of the sectors of potential risk (Tsygichko and Huber, 1998)

collective active force size; 2) new members reduce their active force size by at least 25 percent and modernize forces to meet NATO standards within a reasonable time span (12-15 years); 3) NATO forces in Western Europe are reduced by about 15 percent each commensurate with the additional forces provided by the new members; 4) the surplus of modern equipment resulting from the old members' force reductions is transferred at no cost to the new members (Huber and Friedrich, 1997). While these assumptions were regarded by some as being somewhat unrealistic with a view to the burden sharing records of the Alliance, the results were considered an important contribution to the debate about NATO enlargement in the United States.

2.3.2 Analytical Framework for Restructuring Military Forces

The idea for developing a comprehensive framework for analyzing options for restructuring the Bundeswehr after the end of the Cold War dates back to early 1996 when the German Defence Technology Society invited us to present, at its annual meeting, an assessment of the risks that allegedly came with further reductions of the personnel level of the Bundeswehr for freeing funds for armaments research, development and procurement. In order to cope with defence budget cuts while saving its force structure MoD had reduced defence capital investment funding from an average of 30 percent of the defence budget during in the 1980s to less than 20 percent by 1996 (Huber, 1999). The results of our analysis suggested that a 15-20 percent reduction of the personnel level (of about 350.000 at that time) would permit to return to a capital investment rate of 30 percent of the defence budget within about one decade provided that the 1996 budget level would be sustained in real terms.¹⁶ Conditional to appropriate changes in force structure such a reduction would not imply any risks for Germany's capability to contribute fairly to the foreseeable tasks of the Alliance (Article 5 operations, support of international crisis management and defensive interventions). Moreover, on balance there would not be any negative effects on the labour market considering the economic value of jobs lost in and around the Bundeswehr and jobs saved in the armaments industry benefitting from increased capital investment funding. And most of all, draft equity would not be at risk if the billets for conscripts were reduced in proportion to the overall personnel level (Huber, 1997).

It was the critique in particular of the latter assumption that motivated us to develop a comprehensive analytical framework for addressing problems of defence restructuring that linked, among others, personnel structure options, terms of conscription, personnel cost standards and defence expenditures to the quality and quantity of mission capabilities and force build-up constraints. This framework was applied in a series of studies to analyze the challenges to defence reform throughout NATO Europe for improving its collective out-of area deployment capability to approach U.S. capabilities (Huber and Schmidt, 2000) and to explore the limits of German defence reform for the commission on "Common Security and Future of the Bundeswehr".¹⁷ A paper outlining the analytical approach and selected results of

¹⁶ The Two-plus-Four Treaty (FRG, GDR + France, UK, USA, USSAR) of September 1991 limits the military personnel level of unified Germany's military forces to 370.000. However, a continuous decrease of defence funding in the decade since unification necessitated further reductions of the personnel level to currently 280.000. After the build up phase in the late 1960s, the defence capital investment rate stabilized at about 30 percent of the defence budget which was regarded as necessary and sufficient for a continuous modernization of the Bundeswehr which had a peacetime strength of 500.000 (mainly of combat forces) and a build-up potential to one million by mobilizing reservists and civilian support assets.

¹⁷The Weizsäcker commission was convened by the Federal Government in early 1999 under the chairmanship of the former president of FRG, Richard von Weizsäcker (see footnote 13) to develop recommendations for a new German force structure.

our study for the commission was published in the special issue on “OR in Defence” of the Journal of Operational Research Society (Huber and Schmidt, 2004).

2.3.3 Strategic Uncertainty and Force Planning

During the Cold War period, the force structures of NATO allies reflected the requirement to deter and, if necessary, defeat and aggression by the Soviet Union and the Warsaw Pact. It included the capability to deal with “lesser” requirements that had to be addressed occasionally. However, between the end of the Cold War, and Iraq’s defeat shortly thereafter, and the mid-1990s more than 50 military operations had been undertaken by the US Army to accomplish a series of “lesser” missions” such as ending intra-state conflicts, providing humanitarian assistance and disaster relief, and drug interdiction (Sherwood, 1995). This suggested that operations of the “lesser” kind referred to as *Stability and Support Operations* (SASO) may have become the rule rather than the exception. While militaries that had traditionally been deployed and operated some distance from their home bases, such as the US and, to a lesser degree, UK and French forces, may have been able to cope, by virtue of their force structures, with such a mission environment, the Bundeswehr was not. Designed to defend, together with NATO allies, German territory against short warning mass attacks by Soviet armoured forces supported heavily by artillery and air assets, its active forces consisted mainly of combat forces ready on short notice while the bulk of support capacities would be built up from reservists and civilian assets through mobilization. In other words, in combination with universal conscription this force structure severely limited the capability of the Bundeswehr to participate in non-Article 5 operations out-of-area.¹⁸

In anticipation of the need for analytical support of force structure planning in the emerging mission environment of the 21st century IASFOR initiated research on how to account for the uncertainty associated with the timely demand for and limited duration of “lesser” missions. Based on the assumption supported by the evidence from the Sherwood report, that arrival time and duration of SASO may be described in terms of negative-exponential density functions, a simple queuing simulation model, the Stochastic Requirements Model (STORM), had been developed by Cherry, et al. (1998) to provide insights regarding the capability of given force structures for coping with the uncertainty of the mission environment. The problem with STORM was that it required an excessive number of simulation experiments to generate the relevant data. However, our research on analytical approaches that captured the processes modelled by STORM succeeded by extending the analytical solutions developed for the analysis of telecommunication networks¹⁹ to account for rotation of resources (Schäfer and Huber, 2004) and strategies for dispatching resources or assets available from different organizational entities in a force (Römer and Huber, 2006). The solutions have been tested for plausibility based on a number of hypothetical force capability profiles and a hypothetical spectrum of missions each described in terms of randomly distributed inter-arrival times and durations and the capabilities required for conducting the operations associated with them. They are available for further testing in force planning exercises of national militaries as well as NATO and EU.

¹⁸ It was the very lack of active support assets, in particular of logistics and medical services, that caused the then Chief of Army staff to state in early 1999 that the German Army could not sustain a deployment of more than 7,300 soldiers, out of a total of 234,000 in crisis response operations such as in Bosnia and Kosovo, especially as more than 50% were conscripts not eligible for deployment unless they volunteered to extend their nine-months mandatory service by at least three months (LtGen Willman in the *Süddeutsche Zeitung* of 3 March 1999).

¹⁹ STORM essentially resembles a *multiple service multiple resources* (MSMR) loss network for which a rich collection of analytical solution methods are known.

2.4 Transformation-oriented OR/SA (since 2002)

Stimulated by the respective endeavours in the US and UK and the requirements for non-Article 5 missions, the concept of force transformation was adopted by the Bundeswehr in 2002. Contrary to reform concepts of the 1990s that aimed at defined end states, transformation implies a continuous process of adaptation of the Bundeswehr to meet the tasks emerging in an ever more complex and dynamic security environment. The focus of transformation is on developing the capability for conducting networked joint and comprehensive coalition operations. The responsibility for providing the requisite conceptual and analytical support rests with the *Zentrum für Transformation der Bundeswehr* (ZTransfBw, see footnote 4). Its Division 3 is responsible for the management and assessment of OR studies and the development of M&S systems conducted by industrial contractors, research organizations, and academic institutions.

The director of Division 3, Col Rolf Barth, listed the following focus areas for a further development and application of OR and M&S in the Bundeswehr:

- Adaptation of models and simulations to make them capable of addressing the new tasks and operational concepts emphasizing an effects-based approach to operations taking account of effects in and interdependencies between the political, military, economic, social, information, and infrastructure (PMESII) domains;
- Adaptation of the still largely service-centred training simulation systems to permit training for joint operations of the three services;
- Linking simulation systems with life command and control systems (key word: train as you fight);
- Accounting for human behaviour in models and simulations;²⁰
- Development of agent-based simulation models and data farming approaches for generating potential outcome spaces of and identifying relevant variables for decision support in complex operations;
- Analysis and modelling of complex systems to support *Knowledge Base* development;
- Supporting the development of an integrated simulation and test environment of the Bundeswehr to support concept development and experimentation (CD&E) involving the development of standards, interfaces, and services for linking simulation systems, C2 systems and operational platforms.

In addition to the analysis of problems of international security, my personal research focus after becoming emeritus, and IASFOR being replaced by a new Institute of Applied Systems Science and Information Systems, is directed at Command and Control issues involving a series of conceptual studies funded by ZTransfBw as Germany's contribution to three NATO-RTO research study groups: 1) SAS-026 (Code of Best Practice for C2 Assessment); 2) SAS-050 (Exploring New Command and Control Capabilities); 3) SAS-065 (NATO Network-Enabled Capability C2 Maturity Model). Moreover, together with an interdisciplinary team of the Institute for Technology of Intelligent Systems (ITIS) at the University of the Bundeswehr Munich I was engaged in empirical research funded by the Center of Edge Power of the (US) Naval Postgraduate School in Monterey to test a series of hypotheses on the effects of individual and team characteristics on the performance of small net-worked teams (Huber et al. 2007). The results of experiments involving 130 networked teams of four German Air Force officer candidates and junior officers each, tasked to locate and designate targets

²⁰ IABG has established a special *Human Factors Team* consisting of social scientist and psychologists to support OR analysts and develop models and simulations of the behaviour of individuals, organizations, and masses.

distributed over a terrain grid in a simulated operation, provided new insights as to what degree personality structures, both on the individual and team level, affect team collaboration measured in terms of shared situational awareness and team performance. The findings also support the value chain underlying the concept of Network-Enabled Capability (NEC). The conclusions arrived at are considered as highly relevant for a role-dependent definition of personnel selection and staffing criteria, education and training, and team building. We hope to interest the German MoD in continuing these experiments on a regular basis involving, among others, team tasks of different complexity and team members of other services and nations as well as other (non-military) agencies and with different degrees of field experience.

3 Final Remarks

It should be pointed out that the recollections of the evolution of German military OR since its beginning in the early 1960s presented above do reflect my personal involvement in the process and therefore are neither complete nor balanced by a historian's standards. But they may be regarded as a small contribution to a history of Military OR in Germany yet to be written. Let me conclude by adding a few personal remarks:

- It was an often challenging, but intellectually enriching and satisfying privilege to have been part of the beginning and the evolution of military OR/SA in Germany for more than 45 years.
- The rapid build-up in the 1960s would have been unthinkable without the generous mentorship and friendship extended by individuals and institutions of the established military OR communities in the US and UK.
- I personally feel that the association and cooperation with experienced international colleagues in course of numerous bilateral and multilateral studies and joint endeavours such as organizing scientific conferences and symposia was key to my own professional development. Besides, it was the beginning of many friendships and some cooperative ventures that last to this day.
- In this context I would especially like to express my thanks to the founder of ISMOR, the late Professor Ronnie Shephard, whom I had met first in the mid-1960s in West Byfleet when he was superintendent of land operations analysis at DOAE and I a junior OR analyst at IABG. Together with Jim Taylor, the leader of the Northrop team that introduced me to air war-related OR, Ronnie was one of the early and unforgettable mentors who familiarized me with modelling of land war problems.

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