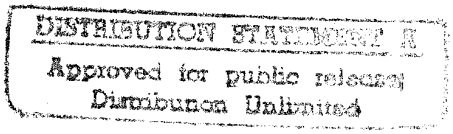
FOA Rapport
D--95--00153-1.1,1--SE
September 1995

The Lanchester Theory of Combat and Some Related Subjects.

A Bibliography 1900 - 1993



Staffan Wrigge
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FÖRSVARETS FORSKNINGSANSTALT
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US Army Concepts Analysis Agency
ATTN: CSCA-TA (Dr. Robert L. Helmbold)
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Bethesda, Maryland 20814-2797

4 December, 1995

Defense Technical Information Center (DTIC-OCP)
8725 John J. Kingman Road, Suite 0944
Ft. Belvoir, VA 22060-6218

Re: Transmittal of Report, "The Lanchester Theory of Combat and Some Related Subjects: A Bibliography 1900-1993"

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Dr. Robert L. Helmbold

GS-14, CSCA-TA

NATIONAL DEFENCE RESEARCH ESTABLISHMENT
Department of NBC Defence
Division of Nuclear Weapons Physics

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FOA No.

Date
November 6, 1995

US Army Concepts Analysis Agency
Attn: CSCA-TA (Helmbold)
8120 Woodmont Avenue
BETHESDA, Maryland 20814-2797
USA

Your reference

Our reference

Dear Sir:

Thank you very much for your two letters and your kind words about our Lanchester bibliography. Your lists of references will certainly be helpful — expecially regarding the development during the last 10 years or so — in case we get the time to issue a revised edition of the bibliography. In fact, my colleague Staffan Wrigge was so stimulated by your letter that he already has proposed such an idea and is prepared to take part in the work. It is too early for myself to say if my time will permit this. By the way, Mr. Wrigge who has corresponded with you about the Russian Osipov, sends his greetings to you.

Now for your question about forwarding the report to DTIC and NTIS. Our report administation group already has sent a copy to the NTIS, so I assume they will make it known through their usual channels (GRA etc.) If you, however, think the report will be made known by more readers, or made known by the "Lanchester community" more effectively by sending it to the DTIC, then I certainly endorse your doing so.

In your second letter of 19 October your have furnished us with very valuable information about the addresses of some researchers in the field. I suppose this is the result of a letter I sent to the Military Operations Society of America asking for such help. Your name was included in the list of people, whose addresses we asked about, to be quite sure that we sent the report to the correct address. It is our understanding that many organizational changes have been made within the U.S. Defense lately, so we thought maybe also the CAA had been influenced. By a mistake our report administrators sent a copy to you instead of awaiting the result of our inquiries.

We have tried to send copies to about 30 American authors of articles and books on Lanchester theory. All of them are mentioned in our bibliography. If you, however, know of other researchers who you think should receive our report, please inform me about them. I also enclose a couple of copies for your own use.

Sincerely,

Lars Wigg

Address:
Lars Wigg
National Defence Res. Establishment (FOA)
S-172 90 STOCKHOLM, Sweden

Enclosure

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FOA Rapport-D--95--00153-1.1,1--SE
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The Lanchester Theory of Combat and Some Related Subjects. A Bibliography 1900-1993

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Arne Fransén
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Sändlista: Hkv/AL, FMV, MHS, FOA 1 {P Agrell, A Almén, T André, U Backlund, B Backström, A Fransén (30 ex), T Isacson, H Löfstedt, S Odar, E Sjöberg, B Söderlund, O Söderqvist, B Tarras-Wahlberg, S Wrigge (30 ex)}, FOA 2, FOA 4 {Bibl, L Wigg (30 ex)}, FOA 6 (B Aulin, I Karasalo, L O Nilsson, P Westrin) + utländska forskare enligt egen sändlista (34 ex)

DOKUMENTDATA

Utgivare Försvarets Forskningsanstalt Huvudavdelningen för försvarsanalys 172 90 Stockholm	Beteckning FOA Rapport-D--95--00153-1.1,1--SE
	Datum: September 1995 / Uppdragsnummer: 541 124
	Projektnamn (ev förkortat) Övrigt OA-stöd
Upphovsman(män) Staffan Wrigge, Arne Fransén, Lars Wigg	Uppdragsgivare FOA

Titel

Lanchesterteori och några besläktade ämnen. En bibliografi för åren 1900-1993

Huvudinnehåll

Föreliggande rapport ger en kort introduktion till Lanchesterteorin, som är en matematisk beskrivning av förlopp och utfall av strider, där vardera sida består av ett antal deltagare. Härvid ges en historik över teorins utveckling i USA och Västeuropa (med ett särskilt avsnitt om Sverige) samt i Östeuropa och f d Sovjetunionen. För varje geografiskt område nämns de institutioner och enskilda forskare som betytt mest för Lanchesterteorins utveckling. Den egentliga bibliografin om ca 700 referenser återfinns i Appendix A, som även innehåller förteckningar över förkortningar, tidskrifter som genomsökts, institutioner och universitet, förläggare m.m. I Appendix B klassificeras referenserna m.h.t. dels ämnen, dels utgivande institutioner.

Nyckelord

Bibliografi, Lanchester, markstrid, stokastiska dueller

Övriga bibliografiska uppgifter	Språk: Engelska

ISSN	ISBN	Omfång: 78 sidor	Pris kronor

Anm.

DOCUMENT DATA		
Issuing organization National Defence Research Establishment Department of Defence Analysis S-172 90 Stockholm	Doc. ref. No. FOA Rapport-D--95--00153-1.1,1--SE	
	Date September 1995	Item designation 541 124
	Project name (abbreviated if necessary) "Other" Operations Research Support	
Author(s) Staffan Wrigge, Arne Fransén Lars Wigg	Initiator or sponsoring organization FOA	

Title

The Lanchester Theory of Combat and Some Related Subjects. A Bibliography 1900-1993

Abstract

This report gives a brief introduction to the Lanchester theory, which is a mathematical description of the course and outcome of battle with several participants on either side. Thus we present a history of the development of the theory in the United States and Western Europe (with a separate section about Sweden) as well as in Eastern Europe and the former Soviet Union. For each geographical area we mention the institutes and individual scientists who have had the most impact on the development of Lanchester theory. The bibliography as such comprises some 700 references and is found in Appendix A, which also contains lists of abbreviations, magazines which have been searched, institutes and universities, publishers etc. In Appendix B the references are classified according to application or mathematical approach. They are also classified as to issuing institute or agency.

Key words

Bibliography, ground battle, Lanchester, stochastic duels

Further bibliographic description	Language
	English

ISSN	ISBN	Pages	Price
		78	

Preface

This report is the joint work of three persons, all of whom have worked for many years at the National Defence Research Establishment (FOA) in Sweden. We have all been involved in making models of different aspects of battles including all the military services. During this work we have come into contact with the Lanchester theory of combat which we consider as an important tool in model building.

Two of us, S Wrigge and L Wigg, have systematically gathered information concerning Lanchester theory since the early 1970s. In 1975 we compiled a bibliography on the subject. Since then twenty years have passed and quite a few papers (reports, books) about Lanchester theory have seen the daylight. Thus we have found time to be ripe for a new bibliography, which is presented here.

The third of us, Arne Fransén, has contribued with his expert knowledge of computers and data bases. He has arranged all the information in a data file. He has also carefully checked many of the references against the original documents (or microfiches thereof).

It can hardly be claimed that this bibliography is complete. This is emphasized by the complement at the end of section 7 in Appendix A. This complement is mainly the result of a study of the reference lists of a number of Lanchester reports.

We welcome, of course, all comments on this bibliography as well as corrections and additions. Those should be sent to Lars Wigg, FOA, S-172 90 Stockholm, Sweden. (The other two authors will soon be leaving FOA.)

Contents

INTRODUCTION

1. Definitions and general background

The Lanchester theory of combat is most easily defined as a mathematical description of the course and outcome of real or simulated battle or of situations of a similar nature - such as the struggle for market shares. The tools which are used are most often differential equations and/or stochastic processes. The "Lanchesterians" consider their theory of battle as a part of physics (see e.g. Brackney (86)).

The theory has received its name from one of its creators, F W Lanchester (1868-1946), an English gentleman of numerous talents and interests. Its other creator was for many years virtually unknown in the West. His name was M Osipov (18??-19??), and his background is so obscure that it is not even known what the initial "M" stands for. Both Lanchester's and Osipov's work is from the 1914-1916 period. Since they worked independently of one another, one should properly speak of the Lanchester-Osipov theory of combat. We believe that this designation will become customary among military analysts in the future.

A more detailed description of Lanchester's life and work is to be found in the references given in section 2.1. Although far less complete, the corresponding data for Osipov is given in section 2.3. (A predecessor of both is the American officer B A Fiske, who as early as 1905 published a simple discrete version of one of the Lanchester-Osipov equations (see especially section 2.1).)

The title of this bibliography includes the words "and some related subjects". This refers mainly to mathematical models of duels, which is a well-defined area of research. Another area included is movement of the frontline in battles or campaigns. There are also studies of the frequency, duration and extent of labour strikes and of wars. As mentioned above, we have also included references to papers treating struggles for market shares and similar competitive situations. Finally, we have included references to more extensive combat models which we know or strongly believe are built upon Lanchester theory.

In a previous bibliography (Wrigge & Wigg (615)) biological combat models were also mentioned, since there are many connections between these and Lanchester theory: methods of reasoning and the resulting differential equations are similar in both cases. For reasons of space, however, we have not included these references in the present work.

Surveys of Lanchester models (deterministic and/or stochastic) or of models of duels have been made by C J Ancker (13), C J Ancker & A V Gafarian (19), J Byrne & A Lamontagne (100), L Dolanský (151), L K Ekchian (158), B W Fowler (187, 188), G S Hall (229), N K Jaiswal (295), A F Karr (315), and J G Taylor (538-540). Both an annotated and unannotated bibliography has been compiled by J G Taylor (540). Other lists of valuable references have been included in G S Hall (229) and L Dolanský (151), and an unofficial bibliography was published by P J Haysman and B E Mortagy (246). See also the bibliography by S Wrigge & L Wigg (615).

2. A historic survey

2.1 *United States and Western Europe (except Sweden)*

In our part of the world the pioneer of the mathematical description of combat is, as has already been mentioned, the Englishman F W Lanchester. His basic and often quoted book "Aircraft in Warfare - The Dawn of the Fourth Arm" appeared in 1916. In order to strengthen his military thesis Lanchester was forced to analyze relations between the combatants in different kinds of combat. He published many of his ideas in 1914 in the journal Engineering. A documentation of Lanchester's life and work is given by T von Karman (308), P W Kingsford (338), J F McCloskey (373) and H R Rickardo (440).

In 1905 B A Fiske published a discrete version of one of Lanchester's equations. In a later work, Fiske (184), there is a reference to J V Chase, who published similar results in 1902. As far as we know, this is the earliest reference to what would later be known as the Lanchester-Osipov theory of combat. Fiske's work is discussed by H K Weiss (592) and J H Engel (163).

In the 1920's and 30's the development of the mathematical theory of combat took place mainly in that branch of mathematical biology which deals with the

balance between predators and preys. Important contributions were made by C F Gause, J Lotka and V Volterra.

After the World War II, intensive studies of this subject were made at several American universities and military research institutes. Masses of data from WWII and earlier wars were gathered and analyzed in order to test and develop the Lanchester theory. Contributions by J H Engel (162, 164) and H K Weiss (594) should be mentioned. Lanchester combat theory has been weak when it comes to verification and validation. This painstaking activity almost ceased for a while but was resumed in the 80's and 90's. In this context, works by T N Dupuy (155, 156) and D S Hartley (237-244) can be mentioned.

The main body of references in this bibliography consists of papers, reports and theses produced in the US. Many originate at military research institutes such as the Naval Postgraduate School in Monterey, California and the Institute for Defense Analyses in Arlington, Virginia. As regards Europe, much valuable work has been done in the United Kingdom at DOAE and, to some extent, at the Royal Military College; in Italy at SACLANT ASW Research Centre; in Netherlands at SHAPE Technical Centre; in Germany at IABG in Munich; in Sweden at FOA; in Austria at Institut für Grundlagenforschung an der Landesverteidigungsakademie; and in Switzerland at various institutes and operations research sections within the military establishment.

Our knowledge of what has been done in Lanchester theory and associated areas is of necessity incomplete i.a. because of military classification. Compared with an earlier version of this bibliography from 1975, however, we have been able to fill in several gaps.

In section 3 more details will be given about individual researchers and research institutes.

2.2 *Sweden: The National Defence Research Establishment (FOA)*

As early as the 1950's, FOA developed a serious interest in Lanchester theory and other mathematical descriptions of warfare. An excellent example of this is a paper by T Ganelius (202), in which movement of the front during battle is analyzed using partial differential equations. In the 50's several other scientists at FOA, e.g. B Jansson (297) and L Zackrisson (617, 618, 620) were

well acquainted with Lanchester theory and its ramifications. The first researchers in Sweden to deal with Lanchester theory, however, would seem to be H Wallman *et. al.* (576).

In the 1950's and 60's larger models were created for evaluation of different weapons systems during the test and evaluation phases. In the early '60's the tendency was to use computer simulations and - for assessment of ground battles - ordinary gaming, where different "score methods" were used instead of Lanchester equations. Simulations of ground battle using computers were at a low organizational level, using hit probabilities and geometrical descriptions for the movement of soldiers, tanks etc. In the beginning of the 1970's, operations research teams within the military services (manned by FOA) became involved in problems at a high organizational level (the total military defense structure or a whole service) and interest in Lanchester theory waned.

At the end of the 1970's interest reappeared, however, when insight was gained in the hierarchy of models developed at the Defence Operational Analysis Establishment (DOAE) in the United Kingdom. Of special interest was a method used by D P Dare and D A P James (137) to aggregate measures of effectiveness from a low organizational level to higher levels. The problem of aggregation has gained new emphasis among defense analysts and been fiercely discussed during the 80's as well as the 90's.

Although several researchers at FOA (G Borenius (77, 78), S Wrigge (610-615) and others) have maintained - and to some extent increased - FOA's knowledge of Lanchester theory and similar subjects, it must be acknowledged that the advanced level of the 1950's and 60's has not been sustained. The amount of work required in order to understand and make use of new developments in Lanchester theory has been underestimated. A contributing factor may be disappointments after earlier efforts to use the theory yielded less than had been expected.

2.3 *Eastern Europe and the former Soviet Union*

Owing to the language barrier and a strong inclination for secrecy, it has been difficult to gain a clear view of the situation on the "Lanchester front" in the countries constituting the former Warsaw Pact. It is, however, safe to say that these countries have closely followed what has been published internationally

on Lanchester theory. Soviet textbooks on operations research mention Lanchester equations - deterministic as well as stochastic - as standard methods to predict the outcome of battle. Researchers who have studied the subject in detail, e.g. J W Stirling and J W Anderson[1], are of the opinion that Soviet practitioners of operations research often use theories published in the West, nor have they found there any ideas or theories unknown to Western countries.

Our knowledge of the use of Lanchester theory in the East has increased somewhat since 1975. One should mention contributions by Yu V Chuyev (116), F I Eresko (169), V.M. Gavrilov (208), R L Helmbold (264), V F Krapivin (345), M Osipov (408), P N Tkachenko (569), and V N Zhukov (623). It is from Chuyev that we first learn of Osipov as one of the pioneers of the mathematical theory of combat. R L Helmbold (264) has written about Osipov's life (what little is known) and his pioneering work from 1915. Osipov's work is an example of sound military science, and had his theoretical development been available earlier in the West, a great deal of our analyses of attrition warfare would have been unnecessary. As the saying goes, Osipov was remarkably ahead of his time.

We end this section with a quotation from PHALANX, March 1992, about Osipov:

> "One way to appreciate Osipov is to contrast his work with that of F W Lanchester, who has long been credited with inventing the square and linear law equations that bear his name. His approach is expository and didactic; in other words, he makes no effort to substantiate mathematical logic with data. Osipov in good old fashioned Russian military scientific fashion, derives his equations as theory, then sets about to test the theory with data from 38 battles, then draws conclusions for the pragmatic purpose of aiding those in command of forces of combat."

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[1] J W Stirling and J W Anderson, *Operations Research in the Warsaw Pact armed forces*, Proc 12th US Army Operations Research Symposium, pp 41-48.

3. Sources of information

The references in this bibliography can be presented in three ways, depending on whether one wishes to concentrate on authors, publications or institutions. What follows is a combination of three aspects.

Starting with deterministic Lanchester theory, the most prolific author has been J G Taylor (501-562), who for many years worked at the Naval Postgraduate School in California, USA, which has published most of his research reports. Most of his papers have been published in Naval Research Logistics Quarterly and Journal of the Operations Research Society of America (JORSA). The latter is the journal containing the greatest number of articles on the subject. The frequency of articles on Lanchester theory has, however, declined during the past ten years.

It may be worth mentioning here that the number of publications by J G Taylor and the number of M S theses from the Naval Postgraduate School add up to more than 100, i.e. about a sixth of all references in this report.

On the subject of stochastic Lanchester equations, A F Karr (311-328) is a well-known name. He has been employed at the Institute for Defense Analyses in Virginia, USA. Interesting results have been published by N Jennings (299, 300) and T G Weale (580-587) at DOAE in the United Kingdom. Important work has also been done by C J Ancker and A V Gafarian (19), which includes an annotated bibliography on stochastic Lanchester equations.

A prolific author on the subject of stochastic duels is C J Ancker (8-20), who has worked at the Systems Development Corporation in California, US. Papers by his co-author A V Gafarian (see above), should also be mentioned (198-200).

Another productive scientist is R L Helmbold (248-266), who has worked at several institutes, among them RAND Corporation in California and US Army Concepts Analysis Agency in Maryland, USA. He has, among other things, compared historical data with predictions using Lanchester theory. The RAND Corporation was at an early stage interested in the mathematical theory of combat - see e.g. O Helmer (267), T E Oberbeck (401, 402), and R N Snow

(484). After an interval of low interest, this institute has returned to the subject, although now focusing on problems at a more abstract level - see e.g. P K Davis and D Blumenthal (141).

Leaving aside the pioneering work of M Osipov from 1915, the first effort to validate Lanchester models seems to have been made by J H Engel (162) in 1954, then at the Massachusetts Institute of Technology in USA. Interesting models of battles of the US Civil War have been developed by H K Weiss (594). A mathematical analysis of 60 battles during the Second World War was made by J B Fain (173). Important results also come from D S Hartley at the Oak Ridge National Laboratory in Tennessee (237-244).

Contributions to the area of validation by D Willard (597), J W R Lepingwell (362) and R L Helmbold (see above) should also be mentioned. Generally, it is fair to say that Lanchester theory is underdeveloped in this respect and that this has contributed to its stagnation.

In Western Europe most military research institutes have at times dealt with Lanchester theory. At FOA e.g., approximately 30 reports related to Lanchester theory have been published. We have already mentioned DOAE in the United Kingdom and SACLANT ASW Research Centre in Italy. An overview of what has been published at different institutes is given in *Appendix B*.

One way to follow what is published about Lanchester theory is to read the following publications: JORSA, Naval Research Logistics Quarterly, Government Reports Announcements (GRA) - especially area 15 - and Operations Research: Literatuuroverzicht Wetenschappelijk. The last two publications mentioned give references to reports from NATO countries. Some articles of interest may also be found in the Journal of Canadian Operations Research and the Operational Research Quarterly.

During the last ten years we have also been using computers to search for references in various databases. The results of such searches depend, of course, on how search questions are framed and on which databases are used. Our experience is that all computer searches must be supplemented by manual investigations and literature studies. Also, through the years, many valuable

references have been given to us by colleagues at FOA and elsewhere. We want to take the opportunity here to thank all of them.

Although we have been collecting references to Lanchester theory for some twenty years - and publish here the results of our common efforts - we can hardly claim that this bibliography is in any way complete. It is our hope, however, that we have included the most valuable publications on Lanchester theory and related subjects, and that our readers will benefit from this overview.

4. Use of the bibliography

The main body of the bibliography *(Appendix A)* is a numbered listing of references to books, theses, reports, articles etc, where the authors are listed in alphabetical order. To facilitate use of the bibliography, the reference numbers have also been grouped under various headings. This material is found in *Appendix B*. References to e.g. duels, stochastic Lanchester models, RAND Corporation reports, reports from the Naval Postgraduate School can be found here.

APPENDIX A

0. Preface

In this appendix we give the entire listing of references to papers treating Lanchester and related subjects.

In order to facilitate for the reader we have tried to give enough information in each quoted reference. Thereby we have used some abbreviations, which are listed in Section 1 below.

Section 2 shows the abbreviations used for journals and magazines used as well as country of origin. Section 3 is a listing of the agencies, institutes, universitites etc which have published the reports. Also for the benefit of the reader we have supplied a list of conferences in Section 4 as well as a list of publishers of books in Section 5. A list of acronyms for report identification will be found in Section 6.

The complete listing of references is given in lexicographic order with respect to the authors' surnames in Section 7. To indicate the accuracy of the information the reference number is written in bold type when we actually have seen the document in question. At the end of this section is a complement showing references which were found after the main list had been compiled.

Section 8 gives information about literature, which is referred to in some of the references in section 7.

Table of Contents

1. List of abbreviations used

Amer	American	OR	Operations Research
Appl	Applied	Ph D	Doctor of Philosophy
Assoc	Association	Postgr	Postgraduate
Bull	Bulletin	pp	Pages
Canad	Canadian	Prob	Probability
Co.	Company	Proc	Proceedings
Conf	Conference	Quart	Quarterly
Contrib	Contribution	Rep	Report
Corp	Corporation	Res	Research
ed	Editor	Rev	Review
eds	Editors	Roy	Royal
esp	Especially	Sci	Science
Inc.	Incorporated	Scis	Sciences
Inst	Institute	Ser	Series
Int	International	Soc	Society
J	Journal	Statl	Statistical
Lab	Laboratory	Stats	Statistics
Labs	Laboratories	Symp	Symposium
Log	Logistics	Technl	Technical
Ltd.	Limited	Techno	Technology
M S	Master of Science	Trans	Transactions
Mat	Matematyki	U S	United States
Mathl	Mathematical	Univ	University
Maths	Mathematics	Vol	Volume
Memo	Memorandum	vs	versus
Mil	Military	Zastos	Zastosowania
No	Number		
Opnl	Operational		
Opns	Operations		

2. List of journals and magazines:

Advances in Game Theory
Advances in Game Theory (U S A)
Allgemeinen Schweizerischen Militärzeitschrift (ASMZ)
Allgemeinen Schweizerischen Militärzeitschrift (ASMZ)
Huber & Company Aktiengesellschaft, Presseverlag,
8500 Frauenfeld (Switzerland)
Amer Scientist
American Scientist (U S A)
Annals Mathl Studies
Annals of Mathematical Studies (U S A)
Annals of Opns Res
Annals of Operations Research (U S A)
Appl Stats
Journal of the Royal Statistical Society, Series C,
Applied Statistics (U K)
Army
Army (U S A)
Artilleri Tidskrift
Artilleri Tidskrift (Sweden)
Behavioral Sci
Behavioral Science (U S A)
Bull Amer Mathl Soc
Bulletin of the American Mathematical Society (U S A)
Bull IMA
Bulletin of the Institute for Mathematical Analysis (U K)
Bull Mathl Statistics
Bulletin of Mathematical Statistics (U S A)
Bull de la Societe Royale Belge des Electriciens
Bulletin de la Societe Royale Belge des Electriciens (Belgium)
Cahiers du Centre d'Etudes de Recherche Opérationnelle, Bruxelles
Cahiers du Centre d'Etudes de Recherche Opérationnelle,
c/o Institut de Statistique de l' U. L. B.,
C. P. 210 - Boulevard du Triomphe,
1050 Bruxelles - Belgique (Belgium)
Colloquium Mathematicum
Colloquium Mathematicum (Poland)
Computational and Opns Res
Computational and Operations Research (U K)
Cybernetics - in the Service of Communism
Cybernetics - in the Service of Communism (?)
Defence Sci J
Defence Science Journal (India)
Defense Analysis
Defense Analysis (U K)
DTIC
DTIC (?)

Elementa
Elementa (Sweden)
European J Opnl Res
European Journal of Operational Research (The Netherlands)
History, Numbers and War
History, Numbers and War (U S A)
Int J Systems Sci
International Journal on Systems Science (U S A)
Int Security
International Security (U S A)
Jahrbuch der Wehrtechnik
Jahrbuch der Wehrtechnik (Germany)
J Amer Statl Assoc (JASA)
Journal of the American Statistical Association (U S A)
J Appl Prob
Journal of Applied Probability (U K)
J Canad Opnl Res Soc (CORS)
Journal of the Canadian Operational Research Society (CORS) (Canada)
J Conflict Resolution
The Journal of Conflict Resolution (U S A)
J Franklin Inst
Journal of The Franklin Institute (U S A)
J Mathl Analysis and Applications (JMAA)
Journal of Mathematical Analysis and Applications (U S A)
J Opnl Res Soc
Journal of the Operational Research Society (U K)
J Opns Res Soc Japan
Journal of the Operations Research Society of Japan (Japan)
J Roy Aeronautical Soc
Journal of the Royal Aeronautical Society (U K)
J Roy Statl Soc A
Journal of the Royal Statistical Society, Series A (U K)
J Roy United Services Inst for Defence Studies Quart (RUSI)
Journal of the Royal United Services Institute for Defence Studies Quarterly (RUSI) (U K)
Management Sci
Management Science (U S A)
Der Matematikunterricht
Der Matematikunterricht (?)
Mathl and Computer Modeling
Mathematical and Computer Modeling (U S A)
Mathl Modeling
Mathematical Modeling (U S A)
Mathl Scientist
The Mathematical Scientist (Australia)
Memoirs Defense Academy Japan
Memoirs of the Defense Academy of Japan (Japan)

MIC
: MIC (?)

Mil Rev
: Military Review (U S A)

Nature
: Nature (U K)

Naval Res Log
: Naval Research Logistics (U S A)

Naval Res Log Quart
: Naval Research Logistics Quarterly (U S A)

Normat
: Normat (Scandinavia)

Numerical Methods in Partial Differential Equations
: Numerical Methods in Partial Differential Equations

Obituary Notices of the Fellows of Roy Soc
: Obituary Notices of the Fellows of Royal Society (U K)

Opnl Res Quart
: Operational Research Quarterly (U K)

Opns Res
: (Journal of) Operations Research (U S A)

Opns Res Spektrum
: Operations Research Spektrum (U S A)

Opsearch
: Opsearch (U S A)

Organizational Behaviour in Human Performance
: Organizational Behaviour in Human Performance

OR Overzicht TDCK
: Operations Research Literatuuroverzicht TDCK,
's-Gravenhage (The Netherlands)

PHALANX
: PHALANX (The Bulletin of Military Operations Research
Society), Alexandria, Virginia (U S A)

Proc U S Naval Inst
: Proceedings of the United States Naval Institute (U S A)

Quality Control and Appl Statistics
: Quality Control and Applied Statistics (U S A)

Sankhya B
: Sankhya, Series B (India)

SIAM J Appl Maths
: Society of Industrial and Applied Mathematics Journal on Applied
Mathematics (U S A)

SIAM Rev
: Society of Industrial and Applied Mathematics Review (U S A)

Signal
: Signal (Journal of the Armed Forces Communications and
Electronics Association) (U S A)

Synthese
: Synthese (?)

Teknisk Tidskrift
Teknisk Tidskrift (Sweden)
Trans of the New York Academy Of Sciences
Transactions of the New York Academy of Science, Series II (U S A)
War Gaming Cosmagon and Zigspiel
War Gaming Cosmagon and Zigspiel (?)
Zastos Mat
Zastosowania Matematyki (Poland)
Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM)
Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM) (West Germany)
Zeitschrift für Opns Res
Zeitschrift für Operations Research (Germany)

3. List of institutes

Admiralty Underwater Weapons Establishment
Amer Mathl Soc
Army Command and General Staff College
Army Material Systems Analysis Activity
Ballistic Res Labs
The BDM Corp
The Brookings Institution
Brooks Air Force Base
- School of Aerospace Medicine
Brunel Univ
Carnegie-Mellon Univ
- Department of Statistics
Center for Naval Analyses
Colorado Univ
- Department of Maths
Combined Arms Opns Res Activity
Convair
Defence Materiel Administration (FMV)
Defence Operational Analysis Establishment
Department of the Air Force
Department of National Defense, Canada
Douglas Aircraft Company, Inc.
"Energija"
Florida State Univ
- Department of Statistics
George Washington Univ
Georgia Inst Techno
Government Printing Office
Inst for Defense Analyses
- Program Analysis Division
Institut für strategische Grundlagenforschung an der
Landesverteidigungsakademie des Bundesministeriums für
Landesverteidigung
Iowa Univ
- Department of Statistics
Johns Hopkins Univ
- Department of Mathl Sciences
- Opns Res Office
Joint Publications Res Service
Lambda Corp
Lawrence Livermore National Lab
Louisiana Technical Univ
- College of Administration Business
- Department of Business Analysis Communication
Martin Marietta Energy Systems, Inc.
- Oak Ridge Gaseous Diffusion Plant

Massachusetts Inst Techno
- Lab for Information and Decision Systems
- Opns Res Group
Messerschmitt-Boelkow-Blohm G m b H
- Unternahmensbereich Apparate
Ministry of Defence
- Center for Mil Analyses
National Bureau of Standards
National Defence Res Establishment (FOA)
National Res Council
- Committee on Amphibious Opns
Naval Ordnance Lab
Naval Postgr School
Naval War College
- Center for Advanced Res
- Department of Opns
Naval Weapons Center
North Amer Aviation
Northeastern Univ
- Electronics Res Lab
Oak Ridge K-25 Site
Oak Ridge National Lab
Office of Scientific Res and Development
Ohio State Univ
- Department of Industrial Engineering
- Systems Res Group
Opns Res Gruppe der IABG
The Pentagon
- Organization of the Joint Chiefs of Staff
Physics and Electronics Lab
RAND Corp
Res Analysis Corp
Roy Inst Techno
- Department of Automatic Control
Roy Mil College Sci
SACLANT ASW Res Centre
Sandia Labs
SHAPE Technical Centre
Synectics Corp
System Development Corp
Tactical Weapon Guidance and Control Information and Analysis Center
Technical Opns, Inc.
- Combat Opns Res Group
Univ California
- Department of Economics
Univ Hull
- Department of Mathl Statistics and Subdepartment of Opns Res

Univ Maryland
- Physics Department
Univ Michigan
- Systems Res Lab
  . Department of Industrial Engineering
Univ Microfilms
Univ Microfilms Int
Univ Southern California
- Department of Electrical Engineering
Univ South Florida
U S Air Force Systems Command
U S Army Concepts Analysis Agency
U S Army Engineer School Readings Opns Res/Systems Analysis
U S Army TRADOC Analysis Command
U S Army Weapons Command
- Systems Analysis Directorate Corp
U S Government
Virginia Polytechnic Inst
Wright-Patterson Air Force Base
- Foreign Techno Division
- U S Air Force Inst Techno
  . School of Engineering
  . School of Systems and Logistics
Zentrale Operations-Research-Stelle

4. List of Conferences

1. Advances in Game Theory, Annals of Mathematical Studies 52
   1964
2. Annual Meeting of the Operations Research Society in U S A
   23th 40th
3. Annual United States Army Operations Research Symposium
   4th 10th 11th 12th 13th 17th
4. Conference of Army Mathematics
   24th
5. Carl-Cranz-Gesellschaft Meeting on Bewertung von Waffensystemen
   November 29, 1974
6. Fire Support Method Methodology Workshop
   1975
7. IFORS International Conference on Operations Research
   8th
8. International Conference on Operational Research
   1st 2nd 4th 5th 11th
9. International Symposium on Applied Computations of Operations Research to Problems of World Concern
   1973
10. Los Angeles Joint National Meeting
    November 13-15, 1978
11. Meeting of SIAM
    November 2-4, 1961
12. Military Operations Research Symposium
    8th 14th 35th 57th
13. MIT/ONR Workshop on C3 Systems
    6th
14. National Meeting, Military Applications Section, Operations Research Society of America
    1st
15. NATO Conference on Modeling Land Battle Systems in Military Planning
    August 1974
16. NATO Conference on Recent Developments in Lanchester Theory
    July 3-7, 1967
17. Operations Research Society Annual Conference
    September 6-7, 1979
18. Symposia in Applied Mathematics
    Volume 25
19. University of Michigan Engineering Summer Conference on Military Operations Research
    July 21-August 1, 1969
20. United States Army Engineer School Readings in Operations Research/Systems Analysis
    January 1969
21. Winter Simulation Conference
    December 4-6, 1989

5. List of Publishers

1. American Mathematical Society,
   Providence, Rhode Island
2. Constable and Co,
   London
3. Elsevier Publishing Co,
   New York
4. Gordon & Breach Science Publishers,
   New York
5. Hero Books,
   Fairfax, Virginia
6. John Wiley & Sons,
   New York
7. MacDonald and Jane's Publishers Ltd,
   London
8. National Bureau of Standards,
   Gaithersburg, Maryland
9. North-Holland,
   Amsterdam, The Netherlands
10. Paragon Publishers,
    New York
11. Plenum Press,
    New York
12. Quadrangle Books,
    Chicago
13. R Oldenbourg Verlag,
    München, West Germany
14. Springer Verlag,
    Berlin, Germany
15. The Boxwood Press,
    Pittsburgh
16. The Principia Press, Inc,
    Bloomington, Indiana
17. UNIBOOKS English Universities Press,
    London

6. List of report identifications

AF	U S Air Force
AFIT	Air Force Institute of Technology
AFOSR	(Iowa University)
ARO	Army Research Office
BD	The BDM Corporation
BRL	Ballistic Research Laboratories
CAA	U S Army Concepts Analysis Agency
CEMA	Center for Military Analyses
CNA	Center for Naval Analyses
CORG	Combat Operations Research Group
DAAB	U S Army STAG
DOAE	Defence Operational Analysis Establishment, United Kingdom
FDOK	Flygdokumentation, Defence Material Administration, Sweden
FEL	Physics and Electronics Laboratory
FOA	National Defence Research Establishment, Sweden
GACIAC	Tactical Weapon Guidance and Control Information and Analysis Center
IDA	Institute for Defense Analyses
ISE	???
K	Oak Ridge K-25 Site
LIDS	Laboratory for Information and Decision Systems
MBB	Messerschmitt-Boelkow-Blohm GmbH, Germany
MCOAB	Center for Naval Analyses
NBS	National Bureau of Standards
NPS	Naval Postgraduate School
NWC	Naval Weapons Center
ORG	Operations Research Gruppe der IABG, Germany
ORNL	Oak Ridge National Laboratory
ORO	Operations Research Office
R	RAND Corporation
RF	???
SACLANTCEN	SACLANT ASW Research Centre
SP	System Development Corporation
SRL	Systems Research Laboratory
STC	SHAPE Technical Centre
TPA	North American Aviation
TRASANA	Army TRADOC Analysis Command
TRITA	The Royal Institute of Technology, Sweden
UC	University of California
USAF	U S Air Force
WSEG	Weapons Systems Evaluation Group
ZOR	Zentrale Operations-Research-Stelle, Germany

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APPENDIX B

In this Appendix ordinary numbers and numbers preceded by the letter "C" refer to section 7 of Appendix A. Numbers preceded by an "R" refer to section 8.

1. References classified according to subject matter

a. Allocation of fire etc

(21), (28), (159), (224), (330), (346), (387), (445), (458), (495), (497), (501), (506), (512), (514), (625), (C4), (C43), (C61)

b. Analyses of historical data, validation etc.

(6), (19), (29), (49), (50), (79), (99), (112), (119), (155), (156), (162), (164), (173), (174), (176), (180), (217), (237), (238), (240), (241), (242), (244), (248), (249), (250), (251), (252), (254), (256), (260), (261), (262), (263), (266), (293), (339), (340), (362), (375), (376), (397), (409), (410), (420), (424), (426), (441), (449), (460), (461), (465), (492), (592), (594), (597), (C10), (C18), (C19), (C22), (C48), (C54), (C57), (C70), (C71)

c. Biographical data

(264), (308), (338), (350), (351), (373), (408), (440)

d. Command, control, communication and information

(175), (207), (372), (388), (468), (498), (511), (571), (606), (608), (R27)

e. Comparison of deterministic and stochastic models

(83), (91), (234), (320), (342), (360), (394), (422), (423), (562), (595)

f. Deterministic Lanchester models

(1), (33), (34), (37), (39), (40), (43), (46), (61), (62), (63), (64), (65), (66), (82), (86), (87), (89), (90), (91), (97), (102), (103), (106), (114), (122), (126), (132), (135), (136), (138), (144), (149), (162), (163), (168), (169), (171), (172), (181), (194), (195), (202), (217), (218), (225), (226), (227), (230), (233), (245), (253), (255), (265), (276), (285), (302), (306), (307), (309), (310), (320), (329), (345), (348), (350), (351), (352), (356), (357), (358), (361), (363), (364), (365), (367), (369), (371), (372), (374), (377), (379), (386), (389), (391), (392), (399), (401), (402), (411), (412), (418), (419), (425), (427), (428), (429), (432), (436), (445), (456), (459), (463), (464), (475), (483), (484), (485), (486), (487), (489), (502), (503), (504), (507), (509), (513), (515), (518), (520), (523), (525),

(526), (527), (531), (532), (533), (536), (537), (541), (542), (543), (545), (546), (547), (548), (550), (551), (552), (553), (554), (555), (556), (557), (558), (559), (560), (561), (563), (575), (576), (588), (589), (598), (608), (610), (611), (612), (613), (619), (620), (R24)

g. Duels

(8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (18), (20), (41), (42), (44), (45), (51), (52), (53), (127), (186), (189), (190), (191), (193), (196), (197), (199), (200), (209), (221), (257), (332), (336), (337), (346), (347), (353), (354), (407), (437), (450), (471), (479), (481), (496), (499), (500), (564), (566), (577), (599), (600), (601), (602), (603), (C33)

h. Duration of battles and strikes

(18), (83), (278), (349), (390), (395), (396), (457), (583), (593)

i. Games

(30), (31), (57), (79), (107), (159), (169), (181), (197), (228), (283), (288), (289), (291), (298), (303), (304), (330), (331), (345), (387), (439), (443), (458), (461), (477), (501), (506), (510), (512), (514), (519), (524), (590), (609), (617), (618), (621), (C5), (C6), (C7), (C30), (C60), (C62), (C67), (R5)

j. Markov chains and similar approaches

(41), (42), (44), (45), (294), (335), (438), (454), (455), (578), (591), (621), (C64)

k. Models of air combat

(109), (160), (178), (179), (180), (194), (195), (197), (210), (220), (223), (259), (303), (304), (350), (352), (357), (359), (403), (410), (437), (482), (566), (C1), (C2), (C3), (C4), (C6), (C10), (C13), (C15), (C16), (C25), (C26), (C35), (C36), (C38), (C40), (C42), (C43), (C46), (C55), (C73)

l. Models of guerilla and small units combat

(1), (5), (121), (134), (144), (182), (284), (307), (412), (464), (478), (483), (487), (489), (490), (C53)

m. Models of naval operations

(87), (98), (101), (129), (136), (183), (184), (220), (231), (232), (290), (293), (347), (381), (596), (625), (C47), (C62)

n. Overviews, surveys and bibliographies

(10), (13), (16), (19), (40), (65), (68), (69), (100), (116), (149), (151), (158), (177), (187), (213), (226), (229), (246), (262), (301), (302), (393), (473), (474), (475), (485), (516),

(528), (529), (538), (539), (540), (544), (574), (614), (615), (C22), (C41), (C57), (C63), (R24)

o. Stochastic models and simulation

(7), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (18), (20), (32), (36), (41), (42), (51), (52), (53), (55), (56), (77), (78), (79), (80), (81), (93), (94), (95), (96), (111), (113), (121), (123), (124), (130), (138), (139), (142), (145), (153), (181), (186), (198), (199), (200), (214), (215), (216), (220), (222), (258), (276), (277), (286), (294), (295), (299), (300), (305), (307), (313), (314), (315), (316), (317), (319), (320), (321), (331), (335), (341), (344), (348), (366), (368), (381), (407), (414), (415), (416), (438), (446), (447), (450), (451), (452), (453), (454), (455), (466), (467), (469), (472), (476), (477), (480), (486), (487), (488), (489), (566), (570), (578), (579), (580), (581), (582), (583), (584), (585), (586), (587), (591), (593)

o. Strikes, struggle for market shares

(110), (115), (278), (349), (378), (390), (385), (396), (457)

2. References classified according to publishing institution

Institutions with fewer than four publications have not been included here. Underlined numbers refer to M S theses.

a. Aberdeen Proving Ground

(124), (125), (126), (221), (588), (C27)

b. Air Force Institute of Technology (AFIT)

(112), (355), (357), (430), (472)

c. Carnegie-Mellon University

(142), (414), (415), (416)

d. Center for Naval Analyses (CNA)

(87), (164), (176), (180), (231), (232), (364), (403), (409), (410)

e. Concepts Analysis Agency (CAA)

(262), (263), (266), (408), (616), (C14)

f. Defence Operational Analysis Establishment (DOAE)

(83), (137), (145), (215), (230), (299), (300), (580), (581), (582), (583), (584), (587), (C76). Cf also (324).

g. FOA (National Defence Research Establishment)
(77), (78), (80), (167), (181), (193), (219), (223), (227), (290), (298), (389), (398), (610), (611), (612), (613), (614), (615), (619), (620)

h. Institute for Defense Analyses (IDA)
(21), (22), (23), (24), (25), (26), (27), (28), (54), (171), (311), (312), (313), (314), (315), (316), (317), (318), (319), (321), (322), (323), (324), (325), (326), (327), (328), (C1), (C2), (C35), (C36), (C70), (C71), (C72)

i. Johns Hopkins University
(49), (50), (57), (95), (105), (119), (122), (201), (236), (320), (358)

j. Naval Postgraduate School
(2), (29), (46), (47), (55), (56), (91), (98), (102), (103), (104), (106), (111), (114), (131), (132), (133), (134), (146), (159), (177), (182), (192), (207), (224), (229), (234), (235), (273), (282), (284), (333), (342), (359), (360), (361), (363), (369), (374), (379), (380), (388), (394), (399), (404), (412), (413), (417), (422), (436), (438), (443), (459), (474), (479), (482), (483), (494), (497), (498), (501), (503), (506), (507), (511), (512), (514), (517), (519), (520), (521), (526), (527), (528), (529), (531), (533), (535), (536), (537), (538), (539), (544), (548), (549), (550), (552), (553), (554), (555), (556), (558), (559), (562), (571), (578), (595), (609), (622), (C12), (C31), (C32), (C39), (C43), (C53), (C55), (C62), (C63), (C66), (R28)

k. Oak Ridge National Laboratory (ORNL)
(33), (34), (35), (135), (237), (285), (424), (425), (426), (427), (429), (456), (462), (470)

l. Ohio State University
(61), (120), (121), (C9), (C11), (C54)

m. RAND Corporation
(141), (160), (210), (258), (259), (260), (267), (269), (270), (289), (401), (402), (431), (448), (463), (471), (484), (C7), (C15), (C26), (C48), (C57)

n. Research Analysis Corporation (RAC)
(331), (597), (C8), (C17), (C37), (C38)

o. SACLANT ASW Research Centre
(92), (129), (172), (245), (347), (381), (386), (596), (C47)

p. SHAPE Technical Centre
(113), (405), (406), (607), (C23)

q. System Development Corporation
(8), (11), (599), (600), (601)

r. Technical Operations, Inc.
(143), (248), (250), (251)

s. University of Michigan
(63), (64), (74), (75), (94), (495), (R2), (R3)

t. Vector Research, Inc.
(C25), (C46), (C68), (C69)