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This report presents the results of a conference designed to develop consensus on a workable definition of systems science, determine its potential for solution of Army problems, and develop recommendations for further work if such seems warranted. Conferees made a distinction between systems science (an emerging discipline) and systems approach (a body of systematic technologies). Areas of potential application were identified as those characterized by complexity (in systems of people, equipment, and missions), ongoing change

(in structure or components), information flows, and decision making (especially where relevant information is imprecise, uncertain, incomplete, unreliable, partially inconsistent, or any combination of these).

Two areas recommended as having payoff for further work were: (a) The assessment of battalion operations/effectiveness and (b) The design of complex systems.

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Edgar M. Johnson and T. O. Jacobs

U. S. Army

Research Institute for the Behavioral and Social Sciences

October 1984

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

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Special Report S-8

Perspectives on the Utility of Systems Science in the Army

Edgar M. Johnson, Technical Director

T. O. Jacobs, Chief
Leadership and Management Technical Area

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

October 1984

Army Project Number
2Q162722A791

Manpower, Personnel, and Training

Systems science is an emerging field of inquiry growing out of developments over the past several decades. The Army Research Institute has since its inception used a systems approach, as have investigators in many disciplines. However, support for research on systems science as an area in its own right has been provided only during the past decade.

This special report reflects the continuing search by the Institute for new approaches to meeting the soldier research challenges of the Army. There has been a growing interest by the Army staff and the R&D community in the potential of systems science and a consequent need by the scientific community to assess the probable utility of systems science for near-term as well as future applications to Army requirements. This report provides a summary of the conclusions reached at a working meeting to determine precisely what systems science is, assess its potential for the solution of Army problems, and identify a strategy to pursue in this area. The findings and conclusions serve as a reference point for planning future exploitation of systems science.

EDGAR M. JOHNSON
Technical Director

PERSPECTIVES ON THE UTILITY OF SYSTEMS SCIENCE IN THE ARMY

EXECUTIVE SUMMARY

Requirement:

To examine the current status of systems science and explore its potential for the solution of Army problems.

Procedure:

A working conference was convened which brought together leading systems scientists, other scientists, and key Army leaders among whom some had been instrumental in initiating current force modernization and force integration efforts. Following formal presentations, work groups were formed to resolve the following issues: Is there a definition of systems science on which there is general agreement? Are there Army problems that systems science has clear potential for solving? What are the directions that should be pursued, if any, and who should be responsible for pursuing them?

Findings:

Consensus was reached on a characterization of systems science, as opposed to systems approach, and on a strategy for continued exploration of its utility for aiding the solution of Army problems. Systems science was viewed as an emerging set of constructs and associated taxonomies of aid to understanding, designing, developing, and evaluating systems (one definition). Areas of greatest potential impact are characterized by: complexity - in systems of people, equipment, and missions; ongoing change - in structure or components; information flows, and decision making - especially where relevant information is imprecise, uncertain, incomplete, unreliable, partially inconsistent, or any combination of these.

Two areas were identified as having payoff potential for initial exploration:

a. The assessment of battalion operations/effectiveness. Specific work in this area would focus on understanding the factors that mediate battalion effectiveness, and developing techniques to improve effectiveness.

b. The design of complex systems. Two specific systems were suggested: the All Source Analysis System (ASAS), and the Advanced Field Artillery Tactical Data System (AFATADS).

Utilization of Findings:

The outcomes of the conference provide an azimuth for research to explore the potential offered by the growing systems science discipline to solve Army problems.

CONTENTS

PERSPECTIVES ON THE UTILITY OF SYSTEMS SCIENCE IN THE ARMY

The following is a report of a working conference held on 7-9 December 1983 to assess applications of systems science to Army challenges. The conference was organized in response to a request in the fall of 1982 from Ms. Amoretta Hoeber, Principal Deputy Assistant Secretary of the Army for Research, Development and Acquisition, to assess the potential utility of systems science as a tool for meeting future challenges in the Army. The specific charge to the conference given in Ms. Hoeber's opening address was to:

1. Propose for Army use a definition of systems science on which there is general agreement.

2. Identify future challenges on which there is general agreement that systems science offers a useful approach to generating solutions.

3. Prioritize the directions to be pursued - the best potential payoffs for the limited resources available.

4. Develop a roadmap which specifies what needs to be done, with identification of any research requirements and the means for proceeding.

5. Identify alternative strategies to meeting future challenges where systems science is inappropriate.

6. Identify responsibilities for getting the work done.

To meet this charge, conference participants included scientists and leaders in the systems science, the analytic and R&D community, and the Army. The conference was structured to provide:

a. A partial overview of systems science.

b. A menu of Army challenges and opportunities where systems science may have utility to the Army.

c. A series of working groups to develop alternative positions followed by a plenary session to develop a conference consensus.

The overview of systems science included two major schools of thought: general systems theory by Dr. George Klir, and living systems theory, and its applications within the Army by Dr. James Miller and General Donn Starry (USA Ret). This overview was amplified by focus statements from Dr. Lawrence De Bivort, Dr. Paul Hood, Dr. George Huber, and Dr. Sam Parry.

The overview of Army challenges and opportunities was highlighted by a presentation of Army 21 by MG Donald Morelli. This was followed by a presentation by LTC Walter Mickols, Jr. of key findings from the Army Inspector General special inspection of Force Modernization. Colonel William W. Witt provided a brief summary of the transition of the organizational effectiveness staff officer to the systems integration staff officer. The final presentation of this session was on doctrine for senior leadership by Dr. T. Owen Jacobs. The materials provided by the speakers are included in the tabbed appendices.

Following the formal presentations, the plenary session broke into three working groups: One on force integration; and two on command and control. The initial review of Army challenges indicated that it would be more profitable to establish a second working group on issues of command control rather than a planned working group on force management. The working group reports are included in the tabbed appendices. Following presentations from the working groups in plenary session during the morning of the second day, the conference focused on developing a consensus response to the questions posed in the charge to the conference. The conference agenda and participants are provided in appendices A and B. All of the formal presentations and the working group reports are provided in Volume II of this report (Research Note 84-123). The table of contents of Volume II are provided in Appendix C of this report. The remainder of the report summarizes this position.

A. WHAT IS SYSTEMS SCIENCE?

As a basis for defining systems science, the conference defined a system as:

1. A set of variables.

2. Input - process - output relationships among the variables.

A substantial debate occurred over the issue of what systems science includes or does not include. The debate was resolved by considering the substantial set of disciplines which represent similar, organized systematic approaches to dealing with their own content domains not to be systems science simply by virtue of being systematic. The overarching construct was the systems approach with general systems science a part of this larger construct. The systems approach contains the following disciplines (or conversely these disciplines use the systems approach):

- Systems engineering
- Management science
- Operations research
- General systems science
- Cybernetics
- Information science

General systems science was defined as part of this larger domain. General systems science was defined or characterized as:

- o A conceptual framework to organize inquiry (shared with the systems approach).
- o The study of general structures and properties of systems as reflected in General Systems Theory literature (e.g., Ashby, Beer, Mesarovic, Klir, Miller, von Bertalanffy).
- o A set of constructs and associated taxonomies which are an aid to:
  - Understanding systems.
  - Designing systems.
  - Developing systems.
  - Evaluating systems.

Two key concepts in general systems science which appear to be useful are:

1. Systems should be studied with respect to both their interrelationships with other systems and the interrelationships between components of a system.

2. The use of analogies or quantitative identities with the behavior of living systems.

At this point in time, general systems science is a young, emerging field of inquiry, with relatively few tested hypotheses or operational definitions of parameters applied to different systems. (For a list of published research evaluating and testing cross-level hypotheses, see Appendix E of Volume II. It is an "umbrella" field focused on the relational or structural properties of classes of systems at different levels of aggregation. The computer provides the laboratory for general systems science and there have been few empirical investigations comparing systems science structures with actual systems at different levels. General systems science is not yet an experimental "science" in the classical sense, but is clearly in the formulative stages. It must be used with other tools to be useful and there has been little application to real-world problems (in contrast to the systems approach). The development of general systems science would be enhanced by contact with realistic examples, experimental efforts and hypothesis testing. The recommended azimuth of development is through basic research focused on assessing its applicability; that is, research focused on obtaining and analyzing data from real problems in accord with a theoretical system concept with the intention both of improving the quality of the theoretical model and of solving the specific problem.

B. WHERE MIGHT IT BE USED?

Several issues were identified as possible Army challenges representing potentially fruitful areas of application for a systems approach or general systems science in the areas of force integration, command and control, and information engineering. A third area of potential application, assessment of unit operations/effectiveness especially at battalion level, emerged during the discussions.

The second of these areas merits particular comment. Classically, the area has been termed command, control, communications, and intelligence. Participants were particularly strong in commenting that this has probably contributed to a counterproductive focus on communications technology with its associated hardware, and a lack of focus on the command, control, and information (what is needed) aspects of the total domain. The recommendations strongly focused on the latter.

Issues where general systems science might uniquely contribute were characterized by:

- Complexity (systems of people, equipment and missions).
- Change (in structure or components).
- Information flows.
- Decision making especially where relevant information is imprecise, uncertain, incomplete, unreliable, partially (locally) inconsistent, or any combination of these.

General systems science may be uniquely valuable in the development of solutions to certain problems. It was agreed that the value of general systems science has not yet been demonstrated and there was no agreement that unique applications value actually exist. However, there was agreement that the time is ripe to assess its utility through its attempted application to real problems. Systems science needs to be "painted green" and its relevance to solving specific Army problems established through basic research before setting a course of action. It needs a "safe backwater" to grow and mature, keeping a future perspective -- 10-15-20 years from now. It is too early in its development to know whether systems science will help the Army get where we need to be.

In applying or using systems science, it is important to avoid creating another group with its own unique vocabulary to further confuse the community. There is a need to integrate concepts and tools to create a united front for those who are looking to the R&D community for answers, instead of looking to create a new discipline.

C. WHERE SHOULD WE START?

Each of the three working groups developed a substantial number of candidate applications for a systems approach and a small number for general systems science recognizing that there are other potential approaches

to solving problems in these areas. During the final plenary session, the key recommendation was that basic research should be conducted to assess the relative utility of alternative applications of general systems science to improve understanding and the design, development, and evaluation of selected, specific systems. The research should avoid a narrow focus and be multidisciplinary. The set of potential applications of general systems science from the working groups was reduced to two areas offering the greatest potential payoff to the Army:

1. The assessment of battalion operations/effectiveness.

The thrust of this research area is the development of measurement techniques and evaluation routines for identifying, describing and differentiating why good/effective units are the way they are, and why the not so good/effective units are the way they are. The purpose of the research is the development of a body of knowledge that can be used to develop good/effective units and keep them that way. This research should pick up where earlier battalion level investigations left off. (It was noted that the work initiated in 1978 by TRADOC to investigate the application of systems science to information flow in Army battalions had produced a data base available for further analyses.)

2. Design of complex systems, e.g., the All Source Analysis System (ASAS) or the Advanced Field Artillery Tactical Data System (AFATADS).

The thrust of this research area is the development of systematic procedures for identifying and describing the total system architecture required for effective acquisition, fusion and utilization. It was noted that many information systems are limited by communications architecture and reporting protocols. The purpose of the research is to develop a body of knowledge that can be used to develop effective new information systems and to improve existing systems.

In addition, the attendees concluded that general systems theory provides a potentially useful tool for dealing with change, and its applicability should be explored in issues where challenges of complexity are confronted. The systems integration concept under development at the US Army Organizational Effectiveness Center and School (USAOEC&S) was considered very useful. As part of this initiative, USAOEC&S is an appropriate activity to identify what systems science efforts are ongoing and to collate previous efforts in the Army and other relevant agencies.

D. WHAT ARE THE ALTERNATIVE STRATEGIES?

The conference concluded that there probably are no problem areas with attributes which would make general systems science the uniquely appropriate methodology. A systems approach is uniquely appropriate for many problem areas; however, this overall framework includes methodologies other than systems science. Time precluded a detailed discussion of potential alternative methodologies.

E. SUMMARY

1. A definition of general systems science was generated on which there was general agreement, but with the note that it is an emerging field of inquiry, with relatively few tested hypotheses or operational definitions of parameters applied to different systems.

2. General systems science is one of the fields of inquiry within a broader domain labeled as the systems approach which includes systems engineering, management science, and operations research. Whereas the use of the systems is particularly important to the Army, the application of systems science is still in an early stage of development. It has the potential for being an important tool for better developing the systems approach in the Army.

3. General systems science may offer unique potential when the problem is complex; has flows of imprecise or uncertain information; involves decision making; has people, equipment, and missions; and involves change in one or more of these components. These attributes are found in the broad areas of force integration; command control, and information; and unit operations/effectiveness. However, the value of general systems science has not yet been demonstrated in application.

4. Basic research should be undertaken to access the utility of general systems science to improve understanding and aid in the solution of specific issues in one or more of the following areas: Battalion operations/effectiveness; design of complex information systems. e.g., ASAS or AFATADS.

APPENDIX A

SYSTEMS SCIENCE IN THE ARMY MEETING

December 7-8-9, 1983
Old Colony Inn
Alexandria, Virginia

A G E N D A

WEDNESDAY, DECEMBER 7, 1983

4:00 P.M. REGISTRATION (Main Lobby)

6:30 P.M. RECEPTION (Corner Room / Cash Bar)

7:30 P.M. DINNER (Corner Room)

Keynote Speech
--Ms. Amoretta Hoeber
Principal Deputy Assistant Secretary of the Army
(Research, Development and Acquisition)

THURSDAY, DECEMBER 8, 1983

8:00 A.M. CONTINENTAL BREAKFAST (Commonwealth Lower Foyer)

8:30 A.M. CONVENE PLENARY SESSION (Commonwealth Center)

"Overview of Systems Science: Concept - What Is It?, History, Principle Schools of Thought."
--Dr. George Klir

"Living Systems Theory"
--Dr. James G. Miller

"Applications of Living Systems Theory"
--General Donn A. Starry, U.S. Army Retired

10:15 A.M. COFFEE BREAK (Commonwealth Lower Foyer)

10:30 A.M. RECONVENE PLENARY SESSION (Commonwealth Center)

"Army Challenges and Opportunities - Force Integration: TIG"
--Lieutenant Colonel Walter V. Mikols, Jr.

"Army Challenges and Opportunities - Systems Integration"
--Colonel William W. Witt

"Army Challenges and Opportunities - ARMY 21"
--Major General Donald R. Morelli

"Army Challenges and Opportunities - Doctrine for Senior Leadership: USACGSC"
--Dr. Thomas Owen Jacobs

12:15 P.M. LUNCH (Commonwealth Center)

1:30 P.M. RECONVENE PLENARY SESSION (Commonwealth Center)

Focus Statements: "Unique Focus of Members' Schools of Thought and the Potential for Application to Management of Army Challenges"
--Application Panel Members: Dr. C. West Churchman
Dr. Lawrence De Bivort
Dr. Paul Hood
Dr. George Huber
Dr. Sam H. Parry

Action Planning: Strategy session to develop specific small focus groups.

2:30 P.M. CONVENE CONCURRENT SMALL FOCUS GROUPS (Atrium Rooms and Commonwealth Center - working groups may continue in Atrium Rooms until 11:00 P.M.)

3:15 P.M. COFFEE BREAK (Atrium Rooms and Commonwealth Center)

7:00 P.M. DINNER (Corner Room)

FRIDAY, DECEMBER 9, 1983

8:00 A.M. CONTINENTAL BREAKFAST (Commonwealth Center)

8:30 A.M. CONVENE PLENARY SESSION (Commonwealth Center)

Focus Group Reports Presented to Strategy Group

10:15 A.M. COFFEE BREAK (Commonwealth Center)

10:30 A.M. CONVENE CONFERENCE REPORT PREPARATION (Commonwealth Center)

--User Advisory Panel

12:00 P.M. WORKING LUNCH (Commonwealth Center)

1:00 P.M. RECONVENE CONFERENCE REPORT PREPARATION (Commonwealth Center)

--User Advisory Panel

3:15 P.M. COFFEE BREAK (Commonwealth Center)

5:00 P.M. ADJOURN

APPENDIX B

SYSTEMS SCIENCE IN THE ARMY MEETING

PARTICIPANTS

Colonel John D. Beasley, III
Director, Department of Command
U.S. Army Command and General Staff College
Fort Leavenworth, KS 66027

Dr. Seth Bonder
President
Vector Research, Inc.
P.O. Box 1506
Ann Arbor, MI 48106

Lieutenant Colonel Raymond P. Cadorette
Intelligence and Security Command
4659 Pinto Court
Ellicott City, MD 21043

Lieutenant Colonel Steve Clement
Academy of Health Science
ATTN: HSHA-DCD
Fort Sam Houston, TX 78234

Colonel L. Neale Cosby
Commander
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Lawrence DeBivort
Evolutionary Services Institute
5504 Scioto Road
Bethesda, MD 20816

General William DePuy (RET)
Box 523, Route 1
Delaplane, VA 22025

Mr. Abe Golub
203 Yoakum Parkway
Suite 607
Alexandria, VA 22304

Major John C. Helmick, Jr.
Operations Officer
U.S. Army Soldier Support Center, NCR
200 Stovall Street
Alexandria, VA 22332

Ms. Amoretta Hoeber
Principal Deputy Assistant Secretary of the Army
Research, Development and Acquisition
Department of the Army
The Pentagon
Washington, D.C. 20310

Dr. Robert F. Holz
Chief, ARI Field Unit USAREUR
c/o ODCSPER, HQ USAREUR
APO New York 09403

Dr. Paul Hood
Chief, Program Director
Far West Laboratory for Educational Research and Development
1855 Folsom Street
San Francisco, CA 94103

Dr. George Huber
Department of Management
Graduate School of Business
University of Texas
Austin, Texas 78712

Dr. Thomas Owen Jacobs
Chief, Leadership and Management Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Elliott Jaques
c/o U.S. Army Research Institute
ATTN: PERI-RL
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Edgar M. Johnson
Technical Director
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Chaplain (Major (P)) Herman Keizer
Personnel Staff Officer, Leadership Division
HQDA (DAPE-HRL)
Room 2D742
The Pentagon
Washington, D.C. 20310

Dr. George Klir
Chairman and Professor of the Systems
Science Department
Thomas J. Watson School of Engineering
State University of New York
Binghamton, NY 13903

Dr. Michael Letsky
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Colonel Dandridge M. Malone (Ret)
502 Lighthouse Way
Sanibel Island, FL 33957

Dr. Michael E. Melich
Naval Research Laboratory
Code 7579-NRL
Washington, D.C. 20375

Lieutenant Colonel Walter V. Mikols, Jr.
Assistant Executive Officer
Office of the Army Inspector General
Room 1E736
The Pentagon
Washington, D.C. 20310

Dr. James G. Miller
3337 Campanil Drive
Santa Barbara, CA 93109

Mr. Ronald A. Mlinarchik
Executive Director of the Army Science
Board
Room 2E 673
The Pentagon
Washington, D.C. 21310

Major General Donald R. Morelli
Deputy Chief of Staff for Doctrine
U.S. Army Training and Doctrine Command
Fort Monroe, VA 23651

Dr. Russell O'Neal
4 Liberty Place
Hilton Head Island, SC 29928

Dr. Sam Parry
Naval Post Graduate School
Code 55PY - Naval Post Graduate School
Monterey, CA 93940

Dr. Stephen Pollock
Department of Industrial and Operations Engineering
University of Michigan
1205 Beal Street
Ann Arbor, MI 48109

Dr. Andrew P. Sage
Quarles Professor and Chairman
Department of Systems Engineering
Thornton Hall
University of Virginia
Charlottesville, VA 22901

Dr. Joyce L. Shields
Director, Manpower and Personnel Research Laboratory
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Colonel W. Dean Stanley
Chief, Research and Studies Office
HQDA (DAPE-ZBR), Room 2C733
The Pentagon
Washington, D.C. 20310

GEN Donn A. Starry (USA RET)
1012 Buckingham
Grosse Point Park
Detroit, MI 48230

Dr. Leo Steg
Brookings Institute
1775 Massachusetts Avenue NW
Washington, D.C. 20036

Dr. J. E. Uhlaner
President
Uhlaner Consultants
4258 Bonavita Drive
Encino, CA 91436

Lieutenant Colonel Richard F. Ward
Project Officer for ARMY 21
Office of the Deputy Chief of Staff for Doctrine
Headquarters TRADOC
Fort Monroe, VA 23651

Colonel William Witt
Commandant
U.S. Army Organizational Effectiveness
Center and School
Fort Ord, CA 93941

CONFERENCE COORDINATOR

Lieutenant Colonel Donald M. Rogan
Military Assistant to the Director (MPRL)
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

APPENDIX C