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COMPILATION OF ENERGY EFFICIENT CONCEPTS IN ADVANCED AIRCRAFT DESIGN AND OPERATIONS

Volume I
Technical Report

Information Spectrum, Inc.
955 Louis Drive
Warminster, PA 18974

5 November 1980

Final Report for Period: 10 March 1980 - 5 November 1980

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Naval Air Development Center
Warminster, PA 18974

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Advanced Aircraft Design	Aircraft Engines
Advanced Energy Efficient Concepts	Aircraft Fuel Conservation

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This final report (contained in two volumes) presents the results of research into published literature. The search addressed the technologies necessary to support next generation (IOC 1990+) air vehicle design and operation concepts that will reduce the requirement for natural petroleum-derived energy. The Advanced Concepts Evaluation (ACE) Data Base consists of 599 unique abstracts listed as 948 entries.

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19.

Aircraft Fuel Consumption
Aircraft Fuel Efficiency
Aircraft Fuels
Aircraft Materials
Aircraft Operations Concepts
Aircraft Propulsion Efficiency
Aircraft Structures
Aircraft Unconventional Systems
Alternative Energy Concepts
Alternative Fuels
Alternative Propulsion
Bibliography
Citations
Compilation
Data Base
Energy Conservation
Energy Consumption
Energy Management
National Energy Crisis

20.

The ACE Data Base is arranged into eleven areas of R&D effort, each subdivided into Navy and non-Navy funded programs.

The contents of the respective volumes of this report are as follows:

Volume I - Technical Report - includes introduction, Data Bases searched, research methodology for creation of the ACE Data Base, summary of search results, conclusions and recommendations. This volume contains an appendix of search strategies utilized.

Volume II - Abstract Data Base - contains the ACE Data Base arranged into eleven areas of R&D effort as follows:

- Fuels
  - Synthetic
  - Liquid Hydrogen
  - Other
- Propulsion
  - Gas Turbine
  - Nuclear
  - Advanced
- Aerodynamics
- Structures and Materials
- Flight Performance Management
- Advanced & Unconventional Systems
- Energy Efficient Operation

EXECUTIVE SUMMARY

The United States is currently in a critical period of energy transition. The strategies, policies, and RDT&E programs which the Navy pursues will determine how the current and future energy situation will affect the Navy's ability to successfully accomplish its mission.

The Navy Energy Research and Development (R&D) Program was developed by the Navy Energy and Natural Resources R&D Office (MAT-08E) to identify and assess promising technological solutions to the Navy's present and future operational energy problems. Through its Energy R&D program and assisted by the Systems Commands and Laboratories, the Navy is:

1. Developing and maintaining its status as an informed customer for new energy technologies being developed.

2. Applying energy technology to hardware and systems to increase their energy efficiency.

3. Developing an energy technology base in areas essential to the Navy's mission where that technology is not being developed elsewhere.

Purpose

The specific objective of this effort was to compile and document a list of technologies and advanced concepts consistent with the ACE Project objectives. The identification and documentation of air-vehicle systems concepts, operations concepts, and/or technologies consistent with the project's underlying goal was

to be based on a search of the available technical literature. Such a list would facilitate making intelligent choices regarding further exploration into and development of advanced concepts unique to Navy mission requirements, and which would not be otherwise developed.

Scope

The ACE Data Base comprises 948 entries, of which 599 are unique. These entries were derived from 7659 abstracts retrieved from computer searches of 10 comprehensive data bases. In all, 19 searches were performed. The data bases and search results are listed in Table S-1. The retrieved data items were reviewed and screened for applicability to the ACE Data Base.

The abstracts selected for entry into the data base are presented in a standardized, consistent format as illustrated in Figure S-1. Each entry to the data base contains the following information:

(1) An index number, which identifies the topic and provides unique identification.

(2) An identification number, by which the source document may be retrieved.

(3) The approximate date of the effort.

(4) The performing organization.

(5) An author or principal investigator.

(6) The title of the source document.

TABLE S-1. SUMMARY OF DATA BASES SEARCHED

DATA BASE	NUMBER OF SEARCHES	NUMBER OF ITEMS RETRIEVED
COMPENDEX	1	338
DISSERTATION ABSTRACTS	1	161
DOE	1	127
DTIC	5	32 19 74 80 598
LIBRARY OF CONGRESS	2	983 856
NASA	3	220 157 251
NTIS	3	302 178 895
SCISEARCH	1	8
SSIE	2	42 2338
TOTAL	19	7659

(7) A modified abstract.

(8) A brief description of the kind of publication.

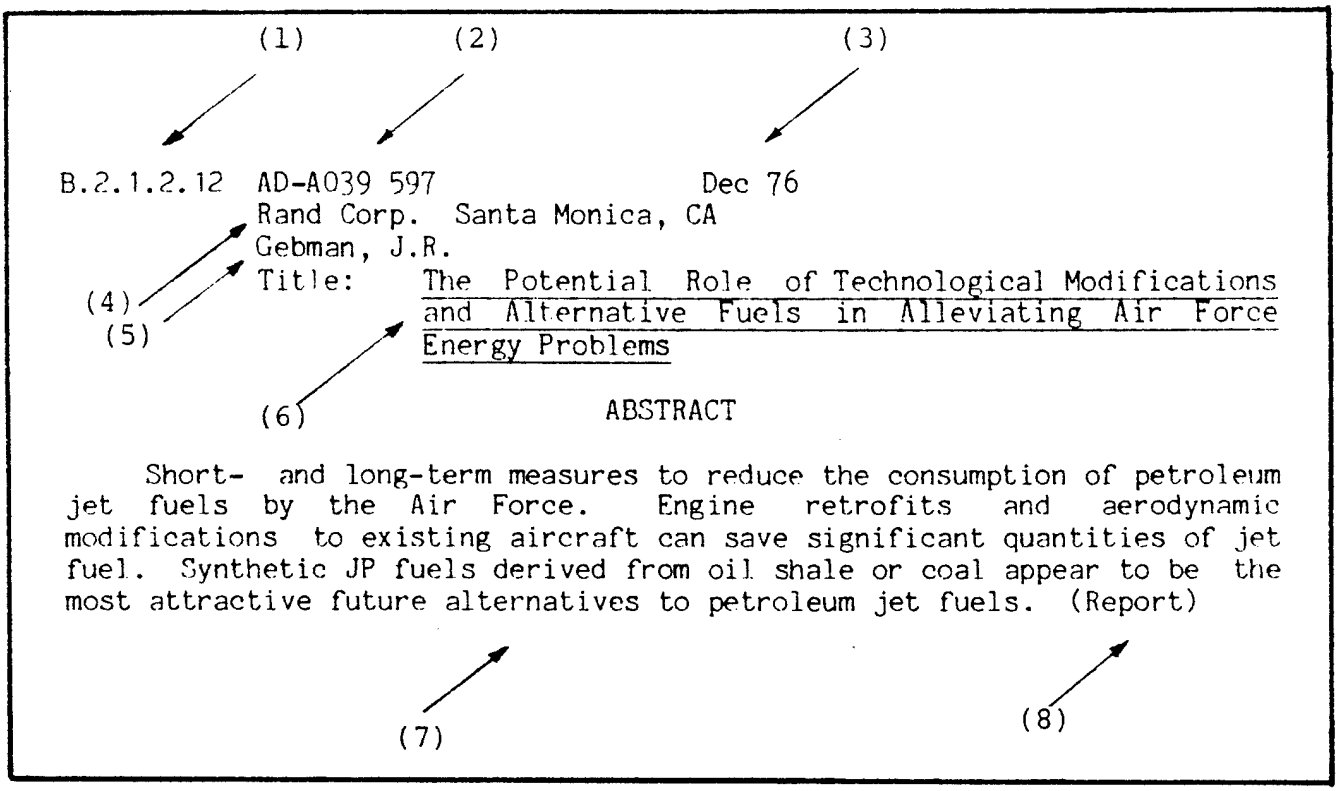

FIGURE S-1. ILLUSTRATION OF DATA BASE ENTRY

Entries in the ACE Data Base were categorized by technology area and Navy and non-Navy sponsorship. These categories are listed in Table S-2 along with their assigned index numbers.

The data base collected, screened, and formatted, was stored in the Naval Air Development Center's Central Computing System. This system consists of two Control Data Corporation (CDC) 6600 computers, one CDC CYBER 170 MODEL 175, and a variety of standard and special peripheral equipment. Data was entered and edited at remote terminals.

TABLE S-2. TECHNOLOGY AREAS AND INDEX NUMBER

INDEX NO.	TECHNOLOGY AREA
	FUELS TECHNOLOGY
	SYNTHETIC FUELS
1.1.1	NAVY FUNDED
1.1.2	NON-NAVY FUNDED
	LIQUID HYDROGEN FUEL
1.2.1	NAVY FUNDED
1.2.2	NON-NAVY FUNDED
	OTHER AVIATION FUEL
1.3.1	NAVY FUNDED
1.3.2	NON-NAVY FUNDED
	PROPULSION TECHNOLOGY
	GAS TURBINES
2.1.1	NAVY FUNDED
2.1.2	NON-NAVY FUNDED
	NUCLEAR PROPULSION
2.2.1	NAVY FUNDED
2.2.2	NON-NAVY FUNDED
	ADVANCED PROPULSION TECHNOLOGY
2.3.1	NAVY FUNDED
2.3.2	NON-NAVY FUNDED
	AERODYNAMIC TECHNOLOGY
3.1	NAVY FUNDED
3.2	NON-NAVY FUNDED
	STRUCTURES AND MATERIALS TECHNOLOGY
4.1	NAVY FUNDED
4.2	NON-NAVY FUNDED
	FLIGHT PERFORMANCE MANAGEMENT
5.1	NAVY FUNDED
5.2	NON-NAVY FUNDED
	SYSTEMS AND OPERATIONAL CONCEPTS
	ADVANCED SYSTEMS CONCEPTS
6.1.1	NAVY FUNDED
6.1.2	NON-NAVY FUNDED
	ADVANCED OPERATIONAL CONCEPTS
6.2.1	NAVY FUNDED
6.2.2	NON-NAVY FUNDED

In order to retrieve data from the ACE Data Base, the user must, upon access to the NADC Computer System, be reasonably facile with the text editing program.

Conclusions

The conclusions reached as a result of this study are presented in two parts. The first part reflects the results of the searches and is presented in a statisitcal manner. The second part is directed to the ACE Data Base itself.

Search

- Navy sponsored research accounts for 9% of the total data base.
- NASA is the greatest contributor, comprising 41% of the data base. Many of the NASA items are symposium and journal papers.
- The Army and private U.S. Industry are the smallest contributors with about 2% each.
- The Air Force is the second largest sponsor, accounting for 18% of the data base.
- Fuels, Propulsion, and Systems/Operations comprise the greatest part of the data base with respect to technology areas. Their contributions are 26%, 23%, and 22% respectively. Flight performance management is the smallest with 2%.
- Within Fuels, Synfuels and LH_2 are about equal, contributing 10% each of the data base.

- In the Propulsion area, Gas Turbine research makes up 83% of the 23% noted above.
- Aerodynamics and Structures/Materials together account for 26% of the data base.
- The Navy's greatest contributions are in Aerodynamics, Synfuels, and Gas Turbine research. Its contributions in Nuclear and Advanced Propulsion, Flight Performance Management, and Energy Efficient Operations are minimal.
- NASA and the Air Force together contribute their greatest effort to Aerodynamics, Gas Turbines, and Advanced/Unconventional Systems. Their lowest contributions are in Nuclear and Advanced Propulsion, and in Flight Performance Management.

ACE Data Base

- The literature searches have identified virtually all published areas of alternate energy sources and air vehicle technology relevant to the ACE project. However, the research identified reflects only work performed or planned prior to the third quarter of FY-80. Since research in the areas of interest is on-going, the ACE Data Base presented in this report has a built-in obsolescence.
- A number of potentially useful data items retrieved during the searches have been rejected because either no abstract was provided, or the abstract was insufficient.

- Very few of the data items provided any fiscal information. Such information could be of value in assessing the relative effort expended in each technology area.
- The retrieved abstracts often did not provide any real measure of success or promise of the reported research. Major problem areas were not usually revealed. Such information would be most useful in assessing the worth of the research.
- Only the first listed name for author or investigator is entered into the ACE Data Base. It could prove helpful to ACE Data Base users to have a complete list of authors/investigators cross referenced to technology research areas.
- The ACE Data Base storage and retrieval method was developed within the constraints of available NADC facilities. Retrieval of data is cumbersome, and takes time, even for an experienced operator. No dedicated user's manual is presently available to the Ace Data Base user.
- The statistical analysis provided may not be a true indicator of relative research effort. A large number of symposium and journal papers written about a single project can grossly outweigh a single report written about another equally important topic.

Recommendations

The following recommendations are made to enhance the ACE Data Base, and to maintain it as an up-to-date valuable tool for Navy users.

- Obtain and review those reports and papers for which insufficient abstract information was available. Abstract and enter relevant items in the ACE Data Base.
- Obtain funding information from contract files and/or by contacting sponsoring and performing organizations. Enter the information in the ACE Data Base, and analyze the relative research efforts by sponsor and technology area. Combine this analysis with the data item distributions.
- For those technology research areas of interest to Navy planners, provide a greater depth of information for the data base. This should be done by providing personal contacts with cognizant individuals in both sponsoring and performing organizations. The information to be elicited should include the following:
  - program title
  - duration of the program
  - primary objectives and areas of R&D
  - primary performing organizations, groups, sections, etc. and responsibilities of each
  - funding to date and current
  - status of research, i.e., progress, success, failure, problems, etc.

  - summary of documentation
  - projection of research activity for specific time periods

- Condense and abstract the data obtained above and enter in the ACE Data Base.
- For those items in the ACE Data Base, retrieve names of all authors/investigators (from original abstracts) and prepare a matrix or cross reference with technology research area. This would be an adjunct to the data base.
- Investigate the various methods of storing and retrieving abstract information. Select one or more promising methods and prepare a conversion plan. The plan should include a simplified user's manual.
- Review the data base items and separate by type of item (report, plan, paper, etc.) and analyze distribution of types of data items by sponsor and technology area. Combine this analysis with funding data to provide a meaningful index of level of effort in each area and by sponsor.
- Provide a continual update of the ACE Data Base. This should be done by periodically updating searches in addition to direct inputs from sponsoring and performing organizations. This latter approach should be arranged as part of the personal contacts noted previously. The arrangement should include at least; inclusion in

report distribution lists, notification of new plans or plan revision, notification of major breakthroughs and problems, and notification of related projects. Updated funding information should also be elicited. The updating of the data base should be performed at least annually.

PREFACE

This Final Report was prepared for the Naval Air Development Center by Information Spectrum, Inc., Warminster, PA under Contract No. N62269-80-C-0200.

This report describes the work covered during the period 10 March 1980 to 24 October 1980, and consists of two volumes:

Volume I - Technical Report

Volume II - Abstract Data Base

The principal Information Spectrum, Inc. contributors to this report were Dr. Sheldon Einhorn, Chief Scientist, and Mr. Richard Shultz, Project Manager and Principle Investigator; under the direction of Mr. Milton Clyman, Executive Vice President. The tedious effort of entering all of the data into the word processing system was shared by Mmes. Geraldine Griffin and Deborah Hochberg of Information Spectrum, Inc.

The authors of this study wish to acknowledge the many valuable contributions provided by the Project Technical Monitor, Mr. Michael Herskovitz, of the Naval Air Development Center. Mr. Herskovitz generated the original structure of the data base, and contributed to establishment of modifications to that structure. He also provided significant assistance to the literature search effort and to the classification of the data.

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1.0 INTRODUCTION

The current energy crisis is familiar to most American citizens as a consumer issue. The implications for the U.S. military establishment are obvious. This section provides background material discussing the energy situation, Navy plans for coping with the problem, and the objectives of this project in particular. It also provides guidance explaining the structure of this report.

1.1 Background

The energy problem, already severe a year ago, has been exacerbated by the political instability in the Middle East. The following three sections relate the general problem to this particular project.

1.1.1 The Energy Situation[1]

The United States is currently in a critical period of energy transition. The strategies, policies, and RDT&E programs which the Navy pursues will determine how the current and future energy situation will affect the Navy's ability to successfully accomplish its mission.

Before 1973, U.S. energy policy was based on the expectation of unlimited supplies of cheap and abundant fuels, and rising rates of energy consumption. The oil embargo of 1973-74 and the quadrupling of prices which followed required a re-examination of these premises, particular in relation to the supply

[1]This background information reflects excerpts from the MAT-08E "Navy Energy R&D Program Plan FY-1979 - FY-1984."

and demand of conventional fuels both in the United States and worldwide.

By most estimates, world production of oil and natural gas will peak at about 40 billion barrels per year before the turn of the century. Perhaps as early as 1985, world demand for these resources may exceed this projected production level. The resulting energy gap could send prices soaring, with serious adverse effects on domestic and international economic systems. Supply interruptions would quickly follow.

At present, one of the most serious energy problems for the United States is the level of foreign imports, which has risen to 47 percent of total U.S. oil consumption. The level of foreign imports has threatened the stability of the dollar, helped to aggravate a widening trade deficit, and made the United States vulnerable to the policies of a relatively small group of oil-producing countries.

As petroleum demand increases in the United States, oil imports are projected to rise to 11.5 million barrels per day by 1985 unless strong measures are taken to reduce our dependence on foreign oil and to develop alternative sources of energy supply. The Administration's National Energy Plan seeks to meet these objectives through conservation measures to reduce current energy demand, substitution of coal for oil and natural gas as a principle fuel source, and development of alternate energy sources.

Experience indicates that 8 to 13 years are required to develop new energy sources from concept to field use, and synthetic

liquid fuels for national defense are not projected to be produced in quantity until after 1990.

Our national security is, therefore, dependent on our ability to guarantee the future availability of energy supplies to meet essential industrial and military requirements. Meeting these objectives will depend on the development of alternate energy sources, particularly liquid fuels, to support worldwide commitments on the seas, in the air, and on the ground. In view of both the long lead times required to develop alternative energy sources and the rate at which our current energy supplies are being depleted, appropriate RDT&E efforts must begin immediately.

1.1.2 ACE Project

The Navy Energy Research and Development (R&D) Program was developed by the Navy Energy and Natural Resources R&D Office (MAT-08E) to identify and assess promising technological solutions to the Navy's present and future operational energy problems. Through its Energy R&D program and assisted by the Systems Commands and Laboratories, the Navy is:

1. Developing and maintaining its status as an informed customer for new energy technologies being developed.

2. Applying energy technology to hardware and systems to increase their energy efficiency.

3. Developing an energy technology base in areas essential to the Navy's mission where that technology is not being developed elsewhere.

The Navy's Energy R&D Program supports the overall Navy Energy Program directed by the Navy Energy Office (OPNAV-413) and described in the Navy Energy Program and Plan document. Guidance for the Navy's Energy Program and the Navy Energy R&D Program is provided by the National Energy Plan and Executive Order 12003.

The Navy Aircraft Fuel Conservation (NAFC) Program has been established within the Navy Energy R&D Program to:

1. Identify feasible design changes to current inventory Navy aircraft for the purpose of reducing the air-fleet fuel consumption. (Near term solutions with 1985 IOC).

2. Review current operating procedures and develop practical alternatives which would result in improved energy efficiency. (Near term solutions with 1985 IOC).

3. Review planned Navy air-systems and recommend design changes and/or alternate operational procedures aimed at enhancing the system's energy efficiency. (Mid term solutions with 1986-1990 IOC).

4. Identify, research, develop,and evaluate the technologies necessary to support the development and subsequent operation of next generation Navy air-systems. Of particular interest are concepts that minimize dependency on crude oil-based fuel. (Far term solutions with IOC 1990+).

The Advanced Concepts Evaluation (ACE) Project is an integral part of the NAFC Program established to pursue this last objective. The ACE Project is the only identifiable effort within the Navy Energy Program addressing Naval Aviation into the 21st century while taking into consideration the declining supplies

of natural petroleum as raw material for aviation fuel. Principal management and technical cognizance are the functions of the Naval Air Systems Command (NAVAIRSYSCOM). The Naval Air Development Center (NAVAIRDEVCEN) is the designated lead technical laboratory for the ACE effort.

The underlying goal of the ACE project is to identify, evaluate, and develop the technologies necessary to support next generation (IOC 1990+) air-vehicle design and/or operations concepts to increase aircraft fuel efficiency and reduce future requirements for natural petroleum-derived energy for propulsion. The operational concepts and mission alternatives will be consistent with the projected 21st century Navy Mission.

Consistent with the above goal, and because RDT&E programs addressing alternate aircraft design and operations concepts may require 10-20 years from concept inception to having a viable system in the fleet, the ACE Project will:

1. Identify and document air-vehicle systems concepts, operations concepts, and/or appropriate technologies consistent with the project's underlying goal.

2. Evaluate these concepts and technologies to:

    a. Establish compatability with current and projected Navy mission requirements.

    b. Gain an understanding of the required RDT&E programs and their cost.

    c. Prioritize the various concepts to facilitate efficient and timely development in view of limited resources.

    d. Make recommendations to upper level program managers as to appropriate Navy course of action.

3. Consistent with NAVAIRSYSCOM directions, develop appropriate concepts, and/or advance (accelerate development of) critical technologies.

1.2 Project Objectives

The objective of this effort was to compile and document a list of technologies and advanced concepts consistent with the ACE Project objectives. Such a list would facilitate making intelligent choices regarding further exploration into and development of advanced concepts unique to Navy mission requirements, and which would not be otherwise developed.

1.3 Structure of Report

This report describes the search methodology used for a literature search supporting the ACE Project objectives; and presents the results of that search, a comprehensive data base. Section 2.0 reviews the methodology used. The data sources are identified and the methods used for searching them are described in Section 2.1. The data items thus identified were further screened, condensed, organized, and stored in a word processing system as described in Section 2.2. The resulting data base was subjected to a limited review and analysis, as discussed in Section 2.3. The results of this review appear in Section 3.0. Two points of view are presented. The first focuses on the areas of R&D effort, the second on the performing organization.

Finally, Sections 4.0 and 5.0 present conclusions and recommendations, respectively, arising out of this effort.

2.0 METHODOLOGY

The search methodology of this effort consisted almost entirely of automated searches of well known data sources, as described in Section 2.1. The resulting set of abstracts was manually screened to eliminate items not appropriate for the project objectives. Those that were retained were categorized and their contents were arranged into a uniform format, for entry into the computer, as described in Section 2.2. The methods used to review and analyze the resulting data base are described in Section 2.3.

2.1 Data Collection

The data from which the ACE abstract data base was derived was obtained from a number of sources. These sources, shown in Table 1, are, in themselves, data bases much broader in scope than that covered by this study. For this reason, each of the selected data base sources had to be searched for the pertinent data items. The selection of suitable data bases and the search criteria used are discussed in the following paragraphs.

2.1.1 Data Base Selection

An initial investigation identified a large number of potentially useful data bases. The following criteria were used to select the data bases to be searched.

1. Sufficient breadth of scope to cover the desired ACE information,

2. Cover reports of work or research completed, in progress, or planned,

3. Cover both U.S. and foreign efforts,

4. Cover military and non-military U.S. Government work as well as industry,

5. Reasonably easy access to the data base,

6. Sufficient retrievable information to form the ACE Data Base,

7. Retraceability of the data.

Ten data bases which met these criteria were selected for the ACE literature search. These bases, comprising Government and commercial sources, are listed in Table 1. Some are accessible through the controlling agency only, some through both the agency and commercial data retrieval services, and some through the latter only. Table 1 also identifies the source (access) used during the automated searches. In some cases, both agency and commercial access were used. The commercial service used in this study is the Lockheed Missiles and Space Company's DIALOG service. Most searches were conducted at NADC through the DIALOG service. Exceptions are noted in Table 1. Each data base accessed during the search is described below.

1. COMPENDEX-
(Engineering Index, Inc.)

The COMPENDEX data base is the machine-readable version of the Engineering Index (EI) (Monthly/Annual), which provides the engineering and information communities with abstracted information from the world's significant engineering and technical

TABLE 1. SUMMARY OF DATA BASES SEARCHED

DATA BASE	NUMBER OF SEARCHES	ACCESS TO DATA BASE (INITIATOR)	NUMBER OF ITEMS RETRIEVED
COMPENDEX	1	DIALOG (NADC)	338
DISSERTATION ABSTRACTS	1	UNIVERSITY MICROFILM INTERNATIONAL (ISI)	161
DOE	1	DOE RECON (DAVID W. TAYLOR NSR&D CENTER) (ISI)	127
DTIC	5	DTIC (ISI) DTIC (ISI) DTIC (NADC TERM) DTIC (NADC TERM) DTIC (NADC TERM)	32 19 74 80 598
LIBRARY OF CONGRESS	2	LCCC (ISI) BIBLIO FILE (ISI)	983 856
NASA	3	NASA RECON (ISI) NASA RECON (ISI) NASA RECON (ISI)	220 157 251
NTIS	3	NTIS (ISI) NTIS (ISI) DIALOG (NADC)	302 178 895
SCISEARCH	1	DIALOG (NADC)	8
SSIE	2	SSIE, INC. (ISI) DIALOG (NADC)	42 2338
TOTAL	19	——	7659

literature. The EI data base provides worldwide coverage of approximately 3500 journals, publications of engineering societies and organizations, papers from the proceedings of conferences, and selected government reports and books. This search was made via Dialog at the NADC terminal.

2. DISSERTATION ABSTRACTS-
(University Microfilms International, Ann Arbor, MI)

Provides information regarding doctoral dissertations, viz. subject, title, author, date, university, and location (volume and page number) in Dissertation Abstracts International where descriptive abstracts may be found. Search was made by University Microfilms International, from key words provided by ISI, and abstracts for the pertinent titles were looked up in the University of Pennsylvania Library. Only the most recent (last several years) dissertations in the Science and Engineering Section were considered.

3. DOE-
(Department of Energy - remote terminal)

The DOE energy data bases comprise the largest and most comprehensive files of worldwide energy information. They cover such subject areas as energy conservation, storage and conversion; coal, petroleum, natural gas, oil shales, and tar sands; solar, geothermal, and nuclear energy; fusion and reactor technology; other synthetic and natural fuels; wind and tidal power; and energy management and policy. This search was made at a remote terminal located at the David W. Taylor Naval Ship Research and Development Center, Annapolis, MD. General guidelines and suggested key words were provided by ISI.

4. DTIC-
(Defense Technical Information Center, Alexandria, VA)

Provides abstracts of reports issued by defense contractors and agencies. Since the data base contains classified information, searches were made from a secure terminal at NADC, and by DTIC upon request by ISI. This data base does not provide the search flexibility of other data bases. Searches can only be made from a dictionary of specific first and second level terms. If the subject of interest does not exactly match these terms, data retrieval is difficult. Five separate searches were made; two by ISI and three by NADC. The ISI terms were very narrow and yielded only 51 items. The NADC searches used very general terms and yielded 752 items, thus requiring more extensive manual review and sorting. The final data base includes no classified information.

5. LIBRARY OF CONGRESS-LCCC-
(Library of Congress Card Catalog)

This is a computer stored and accessed card file of LC books. Subject headings are provided in a LC catalog or dictionary. These headings are inserted into a local terminal at LC, and Card Catalog data for listed books are displayed (or printed). Only title, author, date, publisher, LC call number, Dewey Decimal number, and ISBN number are given. No abstract data are available. LC publishes pamphlets called "LC Tracer Bullet" for major subjects of interest. In addition to selected texts, handbooks, encyclopedias, dictionaries, and bibliographies, they also list more specific subject headings.

For example: the Tracer Bullet entitled "Coal Gasification" lists the following subject headings:

- Coal Gasification (Highly relevant)
- Coal Gasification, Underground (Highly relevant)
- Coal (Relevant).

In general, text book entries proved of little value to the ACE data base. Their field of interest is rather broad and they do not indicate who is (was) conducting the research.

6. LIBRARY OF CONGRESS-BIBLIO FILE -

This is a listing of titles/captions in periodicals (magazines, journals, newspapers, etc) in a computer file. The titles are only those used by Congressional researchers for specific investigation. No authors nor affiliations are noted, and the same entry often appears many times under different file numbers. The usefulness of this source is also minimal since articles of interest are noted in much greater detail in other data bases.

7. NASA-
(National Aeronautics and Space Administration Scientific and Technical Information Facility)

The NASA data base covers a number of individual data bases, the two most pertinent ones being STAR (Scientific and Technical Aerospace Reports) and IAA (International Aerospace Abstracts). The STAR base lists all pertinent reports related to NASA research and contracts. IAA lists articles, papers, symposia, etc. of

interest. Three separate NASA searches were made by NASA upon ISI request. ISI provided general guidance and suggested key words. The first two searches were aimed primarily at alternate energy sources, while the third was aimed at conservation measures.

8. NTIS-
(National Technical Information Service, U.S. Department of Commerce, Springfield, VA)

The NTIS data base consists of government-sponsored research, development and engineering, plus analyses prepared by federal agencies, their contractors or grantees. It is the means through which unclassified, publicly available, unlimited distribution reports are made available for sale from such agencies as NASA, DTIC, DOE, HEW, HUD, DOT, Department of Commerce, and some 240 other units. Three searches were performed; two by ISI request to NTIS using general guidance and suggested key words, and the third on the NADC terminal (via DIALOG) using a broader approach. The two ISI searches yielded 480 items while the NADC search yielded 895 items, requiring greater manual selection effort.

9. SCISEARCH-
(Institute for Scientific Information, Philadelphia, PA)

SCISEARCH is a multidisciplinary index to the literature of science and technology prepared by the Institute for Scientific Information. It contains all the records published in Science Citation Index (SCI) and additional records from the Current Contents series of publications that are not included in the printed version of SCI. This was a short search conducted

at the NADC terminal (via DIALOG). Only eight items of interest were retrieved, and no further effort was expended on this data base.

10. SSIE-
(Smithsonian Science Information Exchange Inc. Washington, D.C.)

SSIE is a data base containing reports of both government and privately funded scientific research projects, either currently in progress or initiated and completed during the most recent two years. SSIE data are collected from the funding organizations at the inception of a research project and provide a source for information on current research long before first or progress reports appear in the published literature. SSIE encompasses all fields of basic and applied research in the physical and engineering sciences.

A small amount of material is provided from private industry and foreign research organizations, while 90% of the information in the data base is provided by agencies of the federal government. Two searches were made: one from SSIE Inc. requested by ISI using general guidance and suggested key words; and the other by NADC terminal (via DIALOG). The ISI initiated search yielded 42 items compared to the broader NADC search which yield 2338 items.

Several other data bases were investigated but not used. These include:

- Chemical Propulsion Information Agency, Johns Hopkins Unversity, Baltimore, MD. This data base covers only rocket fuels for space and missile applications.

- Electric Power Research Institute. This is a data base concerned with the generation of electric power for general use (public utilities).

2.1.2 Search Criteria

As noted above, two general approaches to the searches were used. One was to provide general guidance and suggested key words to the data analysts responsible for the different data bases, and to let them use their own strategies for searching. In general, this method yielded almost 100% useable data items. However, the number of items lost (not retrieved) is not readily identifiable, and could be significant. The second approach, used with the NADC terminal, was to be very general or broad in specifying key words or topics. Unfortunately, this method results in voluminous outputs, all of which must be manually scanned for retention or rejection.

The key words and strategies (logic and combinations of key words, phrases, topics, subjects, etc.) used for each of the searches are presented in Appendix A.

2.1.3 Elimination of Duplicates

Most of the data bases searched are rather broad in scope, and therefore show a mutual overlap in coverage. In addition, multiple searches were made on individual data bases using different strategies but with some degree of similarity. For these reasons, there appeared a significant number of duplications. In order to eliminate them, the individual data items that were retained after initial screening were sorted alphabetically

by the first listed author or investigator. Where no author/ investigator was listed, the name of the performing organization was used. Data items with the same author were compared for identity using report numbers, NTIS order (AD-) numbers, data base acquisition numbers, dates, titles, and the like. In this manner duplicate items were eliminated prior to final screening.

2.2 Generation of Data Base

The activities described in Section 2.1 resulted in a fairly massive set of abstracts for further consideration. These were subjected to screening as described in Section 2.2.1. Eventually, the screening procedure split the data into two sets - one to be the basis for the ACE Data Base, and the other to be omitted. The items to be retained came from a variety of sources. A single format was established for presentation of the data in a form convenient for prospective users of the ACE Data Base, as described in Section 2.2.2.

The actual storage and printing of the data made use of an established word processing system as described in Section 2.2.3. The capabilities for data retrieval inherent in this system are described in Section 2.2.4.

The ACE Data Base itself, representing the raison d'etre of this report, is bound separately as Appendix B (Volume II). It was subjected to a brief review and analysis, using methods described in Section 2.3.

2.2.1 Screening

All data items from each of the searches were subjected to an initial screening. This involved rapidly scanning the item for words or phrases of interest, or definite non-interest. For example: an abstract that referred to fuel efficiency, alternate fuels or propulsion, or advanced propulsion concepts related to aviation was retained; an abstract that referred to similar items related to ground transportation was rejected. Also rejected were abstracts related to aviation but not concerned with fuels, efficiency, or advanced propulsion. Those items which could not be immediately decided upon were retained.

After removal of duplicates (see Section 2.1.3) the remaining data items were then scrutinized in greater detail for ACE Data Base coding. During this examination, additional rejections were made. Items which were initially questionable were given to other reviewers who had specific expertise, such as engines or aerodynamics. This resulted in additional rejections. Also rejected were items related specifically to space exploration, rocketry, small personal aircraft, or applications which did not lend themselves to naval operations.

A number of data items lacked a suitable abstract, without which no decision could be made. These initially were set aside for further investigation. This meant looking for the original report, article, or paper for an abstract or for more information. Constraints in manpower preclude following this approach to any significant degree, thereby resulting in rejection of these items,too. Papers and articles which were of the survey type,

i.e. broad coverage of natural resources, predictions of future fuel consumption, etc. were also rejected. However, those that projected or predicted technology development which would have an impact on fuel consumption were retained.

In general, the searches included items no more than 10 years old. In a few cases the searches went further back in time. Older items relating to developments that are currently in use and/or are fairly well known in the aviation community were rejected. However, older items that were thought to be of interest today were retained. A typical example is that of nuclear propulsion. Much of the work in this area was done in the 50's and 60's and very little in the mid 70's. A renewed interest, evident in the late 70's, prompted the retention of the earlier items regardless of the dates.

2.2.2 Data Entry Format

The abstracts selected for entry into the data base on the basis of the screening procedure described in Section 2.2.1 were converted to a standard format. This format is illustrated by Figure 1. It includes the following items, as indicated on the figure.

(1) An index number, which identifies the topic and provides unique identification.

(2) An identification number, by which the source document may be retrieved.

(3) The approximate date of the effort.

(4) The performing organization.

(5) An author or principal investigator.

(6) The title of the source document.

(7) A modified abstract.

(8) A brief description of the kind of publication.

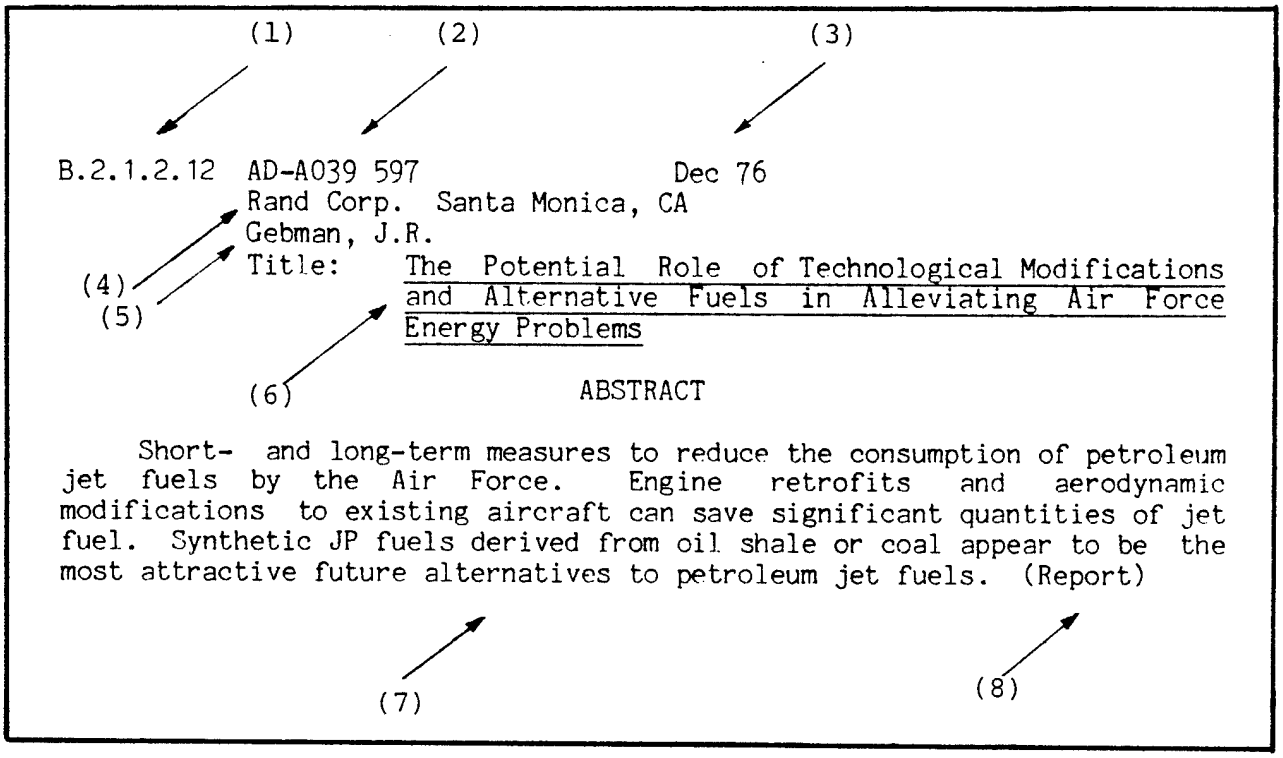

FIGURE 1. ILLUSTRATION OF DATA BASE ENTRY

The user of the data base should be aware of the procedures used to established each of these items in order to use the data base most effectively. These procedures are described in the following subsections.

2.2.2.1 Index Number

The index numbers have the form B.M.N. B simply identifies all entries as part of Appendix B of this report. M is a two- or three-digit code identifying the technology area. These areas were established on the basis of a preliminary review of the

data base. The areas and codes are identified in Table 2. Note that the final digit of the M code distinguishes between Navy funded and non-Navy funded efforts. The number N is a sequential index identifying the entry within ACE Data Base category B.M. For example, the illustration in Figure 1 is the 12th entry in category B.2.1.2 (propulsion technology, gas turbines, non-Navy funded).

Data base entries were assigned codes from Table 2 to correspond to technological areas of significant emphasis as indicated by the abstract. If an entry appeared to have significant content in more than one area, it was assigned multiple code numbers, and the data entry appears in each appropriate file. While many entries appear only once, others may appear two, three, or more times. Accordingly, the total number of entries in the data base (948) is larger than the number of unique data items retained (599).

In general, the meanings of the technology areas identified in Table 2 are self-evident. However, in a few cases clarifying remarks are in order. "Synthetic fuels" comprise fuels of conventional type refined from coal, oil shale, or tar sands. "Advanced propulsion technology" includes engine concepts other than gas turbines or nuclear propulsion - primarily rocket engines. "Flight performance management" refers to airborne control systems for increasing efficiency of fuel utilization. "Advanced systems concepts" includes hardware technologies not covered by previous areas. In addition, it was convenient to

TABLE 2. TECHNOLOGY AREAS AND CODE

CODE	TECHNOLOGY AREA
1	FUELS TECHNOLOGY
1.1	SYNTHETIC FUELS
1.1.1	NAVY FUNDED
1.1.2	NON-NAVY FUNDED
1.2	LIQUID HYDROGEN FUEL
1.2.1	NAVY FUNDED
1.2.2	NON-NAVY FUNDED
1.3	OTHER AVIATION FUEL
1.3.1	NAVY FUNDED
1.3.2	NON-NAVY FUNDED
2	PROPULSION TECHNOLOGY
2.1	GAS TURBINES
2.1.1	NAVY FUNDED
2.1.2	NON-NAVY FUNDED
2.2	NUCLEAR PROPULSION
2.2.1	NAVY FUNDED
2.2.2	NON-NAVY FUNDED
2.3	ADVANCED PROPULSION TECHNOLOGY
2.3.1	NAVY FUNDED
2.3.2	NON-NAVY FUNDED
3	AERODYNAMIC TECHNOLOGY
3.1	NAVY FUNDED
3.2	NON-NAVY FUNDED
4	STRUCTURES AND MATERIALS TECHNOLOGY
4.1	NAVY FUNDED
4.2	NON-NAVY FUNDED
5	FLIGHT PERFORMANCE MANAGEMENT
5.1	NAVY FUNDED
5.2	NON-NAVY FUNDED
6	SYSTEMS AND OPERATIONAL CONCEPTS
6.1	ADVANCED SYSTEMS CONCEPTS
6.1.1	NAVY FUNDED
6.1.2	NON-NAVY FUNDED
6.2	ADVANCED OPERATIONAL CONCEPTS
6.2.1	NAVY FUNDED
6.2.2	NON-NAVY FUNDED

incorporate under this heading items describing general-purpose design methodologies, including computer programs.

"Advanced operational concepts" are procedural, e.g. terminal area operations, towing, use of simulators to replace training flights, etc.

2.2.2.2 Accession Number

Each document had associated with it an accession number by which the document could be uniquely identified within its source data base. These numbers can generally be used to identify the source data base, in accordance with the codes identified in Table 3.

In some cases, one paper was identified in several source data bases. The NTIS number, if available, was preferred.

2.2.2.3 Dates

The dates presented in the ACE Data Base identify the time period when the work was done, whenever this could be determined. Usually it could not. In this case, various alternatives were used. For reports and journal articles, the publication date was entered. For papers presented at meetings or symposia, the date of presentation was used. For announcements of planned work, the date usually reported as "Unknown."

2.2.2.4 Performing Organization

This information is provided when available. For journal articles or symposium presentations it sometimes was available, usually as the author's affiliation, and sometimes not. Addresses

TABLE 3. SOURCE DATA BASE IDENTIFICATION

Leading Characters of Accession Number	Source Data Base
AD*	National Technical Information Service (NTIS)
SSIE	Smithsonian Scientific Information Exchange
nnA**	NASA International Aerospace Abstracts
nnN**	NASA Scientific and Technical Aerospace Reports (STAR)
Nnn**	NASA-generated abstract in NTIS
EI nn**	Engineering Index
AD*	Defense Technical Information Center (DTIC)

* Both NTIS and DTIC use similar accession numbers

** "nn" stands for the last two digits of the year in which the data item was entered into the source data base.

of performing organizations were entered as provided in the source data.

2.2.2.5 Author or Principal Investigator

Whenever the source data item identified multiple authors, only the first name listed was entered into the data base. In a few cases no author or principal investigator could be identified.

2.2.2.6 Title

The exact title of the source document.

2.2.2.7 Abstract

As a rule, the abstract provided is a condensation of the abstract available from the source data base. This condensation emphasized the subject areas of this investigation. Care was taken to have the abstract incorporate words that might be used as an appropriate basis for retrieval.

2.2.2.8 Kind of Publication

The kind of publication may be a report, Master's thesis, plan, journal article, etc. For journal articles, the journal is identified. For technical papers, the meeting or symposium is identified, unless it is incorporated into the title of the paper (e.g., for proceedings).

2.2.3 Storage in Word Processor System

The data base collected as described in Section 2.1 and screened and formatted as described in Sections 2.2.1 and 2.2.2 was stored in the Naval Air Development Center's Central Computing System. This system consists of two Control Data Corporation (CDC) 6600 computers, one CDC CYBER 170 MODEL 175,

and a variety of standard and special peripheral equipment. Data was entered and edited via keyboards at remote terminals, in a conversational mode, communicating through voice quality telephone lines.

Data entry and editing used a resident text editing program, CED 1.0, developed by the University of Calgary, Alberta, Canada. The final printed output was generated by a text processing program, FMT 1.1, also developed at the University of Calgary. These two programs are described in references (a) and (b) respectively.

2.2.4 Data Retrieval

This project entailed the storage of data in the data base, but was not basically concerned with its retrieval. Nonetheless, a brief discussion of the capabilities and limitations of data retrieval is in order for the prospective user of the data base. These qualities are based on the data format described in Section 2.2.2 and on the characteristics of the word processing system described in Section 2.2.3.

The user may select any desired word or numerical document identifier and may use the word processing system to rapidly scan the entire data base to locate all occurrences of this key. The word or number used as a key word need not have been explicitly identified as a key word during the creation of the data base; indeed, no words were called "key words" in this creation. For each occurrence, the system will locate a corresponding

line of input data. It is possible for an individual experienced with the system to identify, extract and print the entire data entry in which this line is imbedded. In view of the subjective decisions involved in creating the data base, as described in Section 2.2.2, the user is advised to use creativity and imagination in such a search.

Furthermore, it is possible, using the standard commands of the word processing system, to generate a subsidiary data base consisting of all data entries identified and extracted as described just above. These, in turn, could be subjected to a further winnowing process. In particular, it is easy to create a subsidiary data base consisting only of certain categories selected from those identified previously in Table 2. This can be accomplished via remote terminal. Next, in order that data retrieval be feasible, the user must be familiar with the CED 1.0 text editing program. Even with such facility, it may be expected that as much as 15 to 30 seconds may be spent interacting with a terminal for each data item extracted.

3.0 SUMMARY OF SEARCH RESULTS

The ACE Data Base generated as described in Section 2.0 was reviewed in two ways. A qualitative review was directed toward determining the state of the art in each technology area, as indicated by the data entries. No attempt was made to assess the value or the validity of the source data items. Such an attempt would have been outside the scope of this effort, and, in any event, would have necessitated review of the source documents, rather than the abstracts, in order to be credible.

The second approach to reviewing the ACE Data Base was statistical. It will be recalled that multiple entries of many of the source items were entered into the data base in more than one technology area. Moreover, the sponsoring agency was identified, whenever possible, for each data item although not entered into the ACE Data Base. Accordingly, it was possible to count each entry in the data base by both technology and sponsoring organization. These counts are shown in Table 4. In trying to read any meaning into these numbers, it must be cautioned that they represent published reports and papers only; not necessarily a true index of effort expended or work accomplished.

Referring to Table 4, it can be seen that Navy data items account for only 9.1% of the total. NASA is by far the greatest contributor, accounting for 40.7% of the entries. Air Force and various foreign sources are next (17.6% and 12.7%), with Army and U.S. Industry (sponsored) trailing with 1.7% and 1.6%

TABLE 4. ACE DATA BASE DISTRIBUTION BY AREAS OF R&D EFFORT

SUPPORTING ORGANIZATION	AREAS OF R&D EFFORT											
	Fuels			Technology Developments						Systems & Operations		
				Propulsion			Aero-dynamics	Struct-ures & Materials	Flight Performance Management	Advanced & Unconv. Systems	Energy Efficient Operations	Total
	Synthetic	LH_2	Other	Gas Turbine	Nuclear	Advanced						
Navy	18	2	7	15	0	2	20	10	1	10	1	86
Air Force	20	12	13	11	7	1	41	19	3	33	7	167
Army	2	0	0	7	1	1	2	3	0	0	0	16
NASA	28	40	18	92	7	3	61	35	8	74	20	386
U.S. Gov't.	9	8	4	7	1	0	5	5	1	7	8	55
Industry	1	3	1	1	0	0	2	1	0	1	5	15
Foreign	9	7	10	33	7	0	15	12	3	12	12	120
Unknown	9	21	9	11	5	2	10	9	5	17	5	103
Tot. Non-Navy	78	91	55	162	28	7	136	84	20	144	57	862
Total	96	93	62	177	28	9	156	94	21	154	58	948

respectively. The Unknown group makes up about 11% of the entries, and there is a good likelihood that many of these are NASA sponsored.

One possible explanation of NASA's dominance of the data items is that, since much of their work is commercially oriented, there is a proclivity toward publicity or general awareness. Although it is not obvious why the Air Force contributes nearly twice as much as the Navy, both with very similar requirements, comparison of the annual aviation R&D budgets of the two services may provide some explanation. The Army, of course, does not have nearly the same aviation needs. The low contribution of U.S. Industry can possibly be explained by the fact that aviation development is largely sponsored by the Government, either civilian or military. Most of the foreign contributions are from the western or NATO nations.

A further breakdown of sponsor contributions to individual technology areas is provided in the following paragraphs, along with the qualitative review.

3.1 Areas of R&D Effort

Three areas of R&D effort are reflected in the data base; fuels, technology developments, and systems and operations. Each is discussed below.

3.1.1 Fuels

Fuels, as encompassed in this data base, comprise 26.5% of the total contribution.

3.1.1.1 Synthetic

Synthetic fuels (or synfuels) composed of coal, shale oil, and tar sand derived fuels comprise 38.2% of the overall fuels, and 10.1% of the total data base. This is the second largest area of contribution by the Navy, which is 18.8% of the total observed synfuel effort by all sponsors. NASA leads in this effort with a 29.2% contribution. The Air Force contributions were 20.8%, which were slightly greater than the Navy's.

A review of the abstracts elicits the following comments:

- Progress in this technology area is fairly advanced. Processes have been developed and at least one pilot plant has been in operation. Synfuels are currently under test by a number of researchers, and major production facility IOC is expected in the next several years. Full scale use of synfuels could be realized in the 1990's.
- Synfuels is the one energy alternative area that would have the least impact on aircraft, engine, and ground facility changes.
- There appear to be some undesirable constituents in synfuels derived by current processes. This may require some engine modifications and/or process refinement. Emission problems are also created.

3.1.1.2 Liquid Hydrogen

Liquid hydrogen (or LH_2) has been singled out because of its major contribution to the fuels technology area. It alone

accounts for 37.1% of the fuels data base portion. The Navy's sponsorship is only 2.1% in this technology, while NASA leads with 43.0%. Although 22.6% is attributed to "Unknown" sponsors, these are most likely NASA sponsored too. Among the identifiable sponsors, Air Force is second with 12.9%.

From the qualitative aspect, LH_2 appears to be highly desirable because it is both abundant and clean. Other comments include:

- There seems to be little evidence of experimental or test effort; the abstracts indicate mostly paper studies and design.
- Studies have been directed primarily toward very large aircraft and SST's. This is probably due to NASA's interest in transports and the Air Force's interest in bombers.
- New aircraft design is required as well as modification of ground facilities (handling, storage, transportation, (etc.).
- The near term economic prospects (especially for commercial aviation) appear to be poor. The long term prospects appear to be much better as the cost of conventional fuel increases.
- A secondary benefit mentioned is the reduction of drag by cooling of aerodynamic surfaces (especially at supersonic speeds) by some of the LH_2.
- LH_2 is often compared to liquid methane (LCH_4) as they share the same problems of cryogenic fuels.

3.1.1.3 Other

This category of fuel technology includes liquid methane, broad-specification petroleum derived fuels, and other chemical/exotic fuels. It accounts for 24.7% of the fuels entries. The Navy's contribution in this category is 11.3%, while NASA continues to lead with 29.0%. Air Force is second with 21.0%, with foreign sources contributing 16.1%. Ignoring the "unknowns", Navy is fourth.

The major consideration in this area is that of broad-specification fuels derived from petroleum. Lower quality petroleum currently obtained has impurities which may be harmful to engines and detrimental to performance. The abstracts reveal research in this regard. Liquid methane also receives some attention, usually in conjunction with discussions of LH_2. The consensus is that LCH_4 is comparable to LH_2.

3.1.2 Technology Developments

This area of R&D effort includes Propulsion, Aerodynamics, Structures and Materials, and Flight Performance Management. Each of these are discussed in the following paragraphs.

3.1.2.1 Propulsion

The category of propulsion, contributing 22.6% of the ACE data base, includes the following subcategories; conventional gas turbine, nuclear, and advanced. Gas turbines contributes 82.7% to the propulsion category, while nuclear and advanced contribute 13.1% and 4.2% respectively.

3.1.2.1.1 Conventional Gas Turbine

The most significant effort in this area, as determined by the number of abstracts, is to improve the fuel efficiency of current type engines. Toward this end, NASA contributes 52.0%, followed by foreign sponsors accounting for 18.6%. The Navy is third with 8.5%. The Air Force's interest amounts to 6.2%, while the others are even lower.

Commercial interest, which include NASA, foreign, and much of the unknown sponsorships, is the prime motivator in this area, weighing almost all of the improvements against fuel savings to determine economic benefits. NASA's Energy Efficient Engine Program accounts for much of the effort. It is interesting to note that only one abstract can be attributed to private industry.

Among the areas of fuel efficiency improvement are:

- higher inlet temperatures
- the use of propellors (turboprops) for subsonic speeds
- variable cycle engines
- closer clearance tolerances

The efforts appear to be evolutionary rather than revolutionary, and an IOC date of 1990 or earlier seems feasible. Research and development efforts have coupled engine efficiency with emission reduction, mandatory for commercial aviation and peacetime flying. Another observation is that material research, especially in the area of high temperature materials (ceramics, alloys, etc.) is an adjunct of engine development.

3.1.2.1.2 Nuclear

The application of nuclear energy to aircraft propulsion has not received much attention. Only 28 abstracts have been noted, which account for 13.1% of the propulsion category, and 3.0% of the overall ACE Data Base. The Navy has contributed nothing, as has private industry. Air Force, NASA, foreign sources, and unknown sponsors have contributed almost equally.

Most of the work in nuclear propulsion was done in the 1950's and 1960's, and very little in the 1970's. However, there was a renewed interest in the late 1970's. The abstracts seem to indicate that only paper studies were performed, with practically no experimental effort. The studies reveal that the application of nuclear propulsion is limited to aircraft with gross weights of one million pounds or greater. Hybrid systems have been proposed; conventional fuels/propulsion for take-off and landing, and nuclear for cruising - with mission durations of about 30 days. As might be expected, attention has been given to safety aspects.

3.1.2.1.3 Advanced

There seems to be little effort in advanced aircraft propulsion that is neither gas turbine type nor nuclear. Only 9 abstracts were collected in this category. This amounts to 4.2% of the propulsion effort, and less than 1% of the total data base. There are only four identifiable sponsors in this area, Navy, Air Force, Army, and NASA, whose contributions are 2, 1, 1, and 3 abstracts respectively.

Although this category is considered as "advanced propulsion", the technology appears to be somewhat conventional. Among the concepts identified were diesel and rotary engines, rocket applications, and electrical methods. Nothing truly unique was found in the searches.

3.1.2.2 Aerodynamics

Aerodynamics plays one of the more predominant roles in research into reducing fuel consumption, being second only to gas turbines. This technology area accounts for 16.5% of the data base. NASA is again the leader with 39.1% of the data items in this group, followed by the Air Force with 26.2%. The Navy is third, contributing 12.8%. Foreign sources make up less than 10%, and private U.S. Industry and the Army have contributed the least.

The objective of aerodynamic research in the area of fuel efficiency or conservation, is to reduce drag. A number of approaches or methods are identified in the abstracts. These include:

- laminar flow/turbulance reduction.
- aero-elastic surfaces.
- supercritical wings.
- winglets.
- aerodynamic surface cooling (often coupled with LH_2 fuel usage).
- forward swept wings. This development appears to be dependent on the use of composite lightweight materials.

Although not specifically a technology development, a number of abstracts identify development of computer programs and other analytical tools to improve the analysis of aerodynamic behavior of bodies and shapes. Apparently the current analytical methods leave much to be desired, resulting in the dependence on wind tunnel testing of conceptual wings, bodies, control surfaces, etc. This is both expensive and time consuming. The new computer programs have, as a goal, the rapid (and less costly) optimization of aerodynamic surfaces.

3.1.2.3 Structures and Materials

This technology area accounts for 9.9% of the entire data base. NASA is the major sponsor, contributing 37.2% of the data items. The Air Force follows with 20.2%. Foreign sources and the Navy are close behind with 12.8% and 10.6% respectively.

The major thrusts in this area are to reduce aircraft weight by the use of lighter weight, less dense materials, and to develop high temperature materials for gas turbine components that are stronger and lighter. A significant portion of the effort seems to be in the development of composite materials for wings, bodies, landing gear, structural elements, and other aircraft components. Mentioned among the composites under development is the use of inorganic fibers, such as boron, graphite, glass, etc., in organic matrices. Also mentioned are metallic matrices. The major areas of concern in the use of composites are strength and fracture resistance, and compatibility with fuels and other aviation fluids (lubricants,

hydraulic oils, coolants, etc.). A considerable amount of research and testing is directed toward these areas. Although not related to fuel efficiency, the cost of manufacturing composite aircraft components receives much attention, especially in the commercial sector. On the other hand, some mention is made of materials and processes which reduce energy consumption during fabrication.

The high temperature material development research is concentrated primarily on ceramics and special alloys for gas turbine components such as rotor blades.

3.1.2.4 Flight Performance Management

This is another area of energy efficiency that appears to have received little attention, based on its contribution of only 21 items (2.2%) to the data base. NASA's sponsorship accounts for 38.1% of these data items; however, this amounts to only 8 items. Other contributions are too few to be meaningful.

The only developments in flight performance management with respect to energy efficiency appear to be the application of on-board computers to control flight in the most fuel conservative manner. It would appear to be most applicable to commercial transport.

3.1.3 Systems and Operations

The areas of Advanced/Unconventional Systems and Energy Efficient Operations are discussed in the following two sections.

3.1.3.1 Advanced/Unconventional Systems

This appears to be one of the more predominant technology areas, comparable to aerodynamics, comprising 16.2% of the data base. Once more NASA is primary contributor with 48.1% of this category. The Air Force accounts for 21.4%. Foreign sources and the Navy are next with 7.8% and 6.5% respectively. U.S. Industry has sponsored only one development in this area (less than 1%) and the Army none at all.

Among the Unconventional approaches, although not altogether innovative, is the use of lighter than air vehicles (LTA). This work, sponsored primarily by the Navy, includes balloons and dirigibles, i.e., rigid and non-rigid LTA's. There is some interest shown in remotely piloted vehicles (RPV) wherein elimination of the pilot, life support systems, and safety features can reduce weight. Included in this technology area are references to very large aircraft (VLA) which were identified under LH_2 fuels and nuclear propulsion. Also included are references to overall aircraft designs and approaches which are energy-efficient, even though the specific approaches are included in the applicable technology areas. This section also includes references to computer-aided aircraft design programs.

3.1.3.2 Energy Efficient Operations

This is one of the smaller areas of the data base, contributing only 6%. Consistently, NASA leads with 34.5% in this area; foreign sponsors follow with 20.7%. The Navy's contribution

is less than 2% (1 data item) while the remaining contributors range from 8.6% to 13.7%. U.S. Industry (airlines) makes its greatest contribution here at 8.6% of the data items in this category.

Among the concepts identified under this category of energy savings, the predominant approaches include modification of cruising altitudes, and flight, descent, and landing patterns. Also included are terminal taxiing and take-off procedures. It appears that current procedures are less than optimum in this regard, and that fuel savings can indeed be realized. Naturally, the greatest impact would be made by commercial aviation, hence the large contributions by NASA and the airlines (U.S. Industry). Other concepts include the use of flight simulators by both commercial and military users to reduce fuel consumption without seriously affecting training and flying proficiency. One novel concept offered is that of towed aircraft for cargo use.

3.2 Supporting Organizations

This section examines each sponsor's contributions to the overall effort, as indicated by the data base items.

3.2.1 Navy

The Navy's greatest contribution is in the area of aerodynamics closely followed by synfuels and gas turbine technology. This is evidenced by 23.3%, 20.9% and 17.4% of their total contribution in these areas respectively. Structures/materials, and

advanced/unconventional systems represent about 11.6% each, while 8.1% of the contributions deal with other fuels. No significant amount of work was reported in any other area.

3.2.2 Air Force

The Air Force also provides its greatest support to aerodynamics technology (24.6%), but follows with advanced/unconventional systems at 19.8%. Synfuels and structures/materials are next at 12.0% and 11.4% respectively. Other fuels, LH_2, and gas turbines are next with 7.8%, 7.2%, and 6.6% reflecting their sponsorship. Nuclear propulsion and operations show contributions of 4.2% each. Little effort is reported in other areas.

3.2.3 NASA

NASA, as noted earlier, is the prime contributor to the data base, accounting for more than 40% of the data items. They appear to have clearly defined responsibilities in the energy savings area through their energy efficient engine and aircraft programs. Their greatest sponsorships, as reflected by the data base, lie in gas turbine engines (23.8%), advanced/unconventional systems (19.2%), and aerodynamics (15.8%). Lesser support, although still significant to the overall data base, is shown for LH_2 (10.4%), structures/material (9.1%), synfuels (7.3%), operations (5.2%), and other fuels (4.7%).

3.2.4 Foreign

Foreign sources, accounting for almost 13% of the data base, represent a mix of countries, mostly western but including

some iron curtain countries and China. The contributions are greatest in gas turbine development (27.5%) and least in advanced propulsion (none). Flight performance management is also low at 2.5%, and the remaining areas are roughly evenly divided, ranging from 5.8% (LH_2 and nuclear propulsion) to 12.5% for aerodynamics. One drawback here is that there is no way of disclosing any research that might be considered classified.

3.2.5 Other

The Army, other U.S. Government agencies, and U.S. Industry represent the least significant of the supporting agencies. They represent 1.7%, 5.8%, and 1.6% of the data base respectively. For individual technology areas, their contributions tend to be minimal or non-existent.

3.3 Performing Organizations

The organizations actually performing the research and development are not always identifiable. This is especially true for symposium papers and journal articles. Where they have been identified, they are noted in the individual abstracts in Appendix B (Volume II). Due to their large numbers, no attempt has been made to determine their distribution. However, it has been noted that they are represented by the aircraft industry, universities, government agencies, independent consulting firms, airlines, and various industrial/manufacturing companies.

4.0 CONCLUSIONS

The conclusions reached as a result of this study are presented in two parts. The first part reflects the results of the searches and is presented in a statistical manner. The second part is directed to the ACE Data Base itself.

4.1 Search

- Navy sponsored research accounts for 9% of the total data base.
- NASA is the greatest contributor, comprising 41% of the data base. Many of the NASA items are symposium and journal papers.
- The Army and private U.S. Industry are the smallest contributors with about 2% each.
- The Air Force is the second largest sponsor, accounting for 18% of the data base.
- Fuels, Propulsion, and Systems/Operations comprise the greatest part of the data base with respect to technology areas. Their contributions are 26%, 23%, and 22% respectively. Flight performance management is the smallest with 2%.
- Within Fuels, Synfuels and LH_2 are about equal, contributing 10% each of the data base.
- In the Propulsion area, Gas Turbine research makes up 83% of the 23% noted above.
- Aerodynamics and Structures/Materials together account for 26% of the data base.

- The Navy's greatest contributions are in Aerodynamics, Synfuels, and Gas Turbine research. Its contributions in Nuclear and Advanced Propulsion, Flight Performance Management, and Energy Efficient Operations are minimal.
- NASA and the Air Force together contribute their greatest effort to Aerodynamics, Gas Turbines, and Advanced/Unconventional Systems. Their lowest contributions are in Nuclear and Advanced Propulsion, and in Flight Performance Management.

4.2 ACE Data Base

- The literature searches have identified virtually all published areas of alternate energy sources and air vehicle technology relevant to the ACE project. However, the research identified reflects only work performed or planned prior to the third quarter of FY-80. Since research in the areas of interest is on-going, the ACE Data Base presented in this report has a built-in obsolescence.
- A number of potentially useful data items retrieved during the searches have been rejected because either no abstract was provided, or the abstract was insufficient.
- Very few of the data items provided any fiscal information. Such information could be of value in assessing the relative effort expended in each technology area.

- The retrieved abstracts often did not provide any real measure of success or promise of the reported research. Major problem areas were not usually revealed. Such information would be most useful in assessing the worth of the research.
- Only the first listed name for author or investigator is entered into the ACE Data Base. It could prove helpful to ACE Data Base users to have a complete list of authors/investigators cross referenced to technology research areas.
- The ACE Data Base storage and retrieval method was developed within the constraints of available NADC facilities. Retrieval of data is cumbersome, and takes time, even for an experienced operator. No dedicated user's manual is presently available to the ACE Data Base user.
- The statistical analysis provided may not be a true indicator of relative research effort. A large number of symposium and journal papers written about a single project can grossly outweigh a single report written about another equally important topic.

5.0 RECOMMENDATIONS

The following recommendations are made to enhance the ACE Data Base, and to maintain it as an up-to-date valuable tool for Navy users.

- Obtain and review those reports and papers for which insufficient abstract information was available. Abstract and enter relevant items in the ACE Data Base.
- Obtain funding information from contract files and/or by contacting sponsoring and performing organizations. Enter the information in the ACE Data Base, and analyze the relative research efforts by sponsor and technology area. Combine this analysis with the data item distributions.
- For those technology research areas of interest to Navy planners, provide a greater depth of information for the data base. This should be done by providing personal contacts with cognizant individuals in both sponsoring and performing organizations. The information to be elicited should include the following:
  - program title
  - duration of the program
  - primary objectives and areas of R&D
  - primary performing organizations, groups, sections, etc. and responsibilities of each
  - funding to date and current
  - status of research, i.e., progress, success, failure, problems, etc.

  - summary of documentation
  - projection of research activity for specific time periods

- Condense and abstract the data obtained above and enter in the ACE Data Base.
- For those items in the ACE Data Base, retrieve names of all authors/investigators (from original abstracts) and prepare a matrix or cross reference with technology research area. This would be an adjunct to the data base.
- Investigate the various methods of storing and retrieving abstract information. Select one or more promising methods and prepare a conversion plan. The plan should include a simplified user's manual.
- Review the data base items and separate by type of item (report, plan, paper, etc.), and analyze distribution of types of data items by sponsor and technology area. Combine this analysis with funding data to provide a meaningful index of level of effort in each area and by sponsor.
- Provide a continual update of the ACE Data Base. This should be done by periodically updating searches in addition to direct inputs from sponsoring and performing organizations. This latter approach should be arranged as part of the personal contacts noted previously. The arrangement should include at least: inclusion in

report distribution lists, notification of new plans or plan revision, notification of major breakthroughs and problems, and notification of related projects. Updated funding information should also be elicited. The updating of the data base should be performed at least annually.

REFERENCES

(a) Technical Memorandum 85-7802, Revision F, "CED 1.0, A Text Editor," Naval Air Development Center, 6 November 1978.

(b) Technical Memorandum 85-7801, Revision D, "FMT 1.1, A Text Processor," Naval Air Development Center, 14 April 1979.

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APPENDIX A
KEY WORDS AND SEARCH STRATEGIES

APPENDIX A

GENERAL GUIDANCE AND SUGGESTED KEY WORDS FOR: DOE, DTIC, NASA, NTIS, & SSIE

Identify technologies and past or on-going research, studies, or effort necessary to support new air-vehicles design and/or operation concepts that are independent of petroleum-based energy for propulsion. Application is for Navy air missions in time-frame of year 2000 and beyond.

Consider all inputs from 1970 to present

- Aircraft/Air Vehicle/Aviation
- Propulsion/Engines
- Fuels/Energy
  - alternate
  - other
  - synthetic
  - non-petroleum
  - exotic
  - conversion
  - research
  - new
  - innovative
  - propellant
  - non-fossile

Chemical energy conversion
Energy conservation
Energy research
Energy production
Alternative energy systems
Hydrogen
Hydrogen fuel
Liquid propellant
Solid propellant
Fuel cells
Coal liquefaction
Synthetic fuels
Aircraft fuel
Shale oil
Coal
Oil shale
Solid fuels
Solid fuel other
Liquid fuels
Liquid fuels other
Energy consumption
Energy utilization

Consider all inputs from 1970 to present (Continued)

MHD (Magnetohydrodynamic)
Rocket engines
- technology
- components
- liquid propellant
- solid propellant

DIALOG File8: COMPENDEX 70-80/MAR (Copr. Engineering Index Inc.)

Set	Items	Description
1	5319	SERIAL# 3W7Z
2	3527	INTERCONNECT?
3	1297	CONNECTOR?
4	32684	SPACE?
5	4511	ROCKET?
6	1445	ASTRONOM?
7	115888	CONTROL?
8	3903	MISSILE?
9	51302	STRESS?
10	765	FASTENER?
11	5384	INSPECT?
12	0	FATIGUE?
13	110239	TEST?
14	26736	STABILIT?
15	10056	FATIGUE?
16	42	CCV?
17	115888	CONTROL?
18	358	CONFIGURED?
19	15226	VEHICLE?
20	1250	MANEUV?
21	1	FLY BY WIRE?
22	0	FBY?
23	1	FLY(W)WIRE?
24	20	DIRECT(W)LIFT(W)CONTROL
25	27	DLC?
26	40	24+25
27	41352	COST?
28	3233	1-(2+3+4+5+6+7+8+9+10)
29	2105	28-(11+12+13+14+15+16+17+18+19+2)
30	1895	29-(21+22+23+24+25+26+27)
31	7950	CONSERV?
32	23	30*31
33	10	FBW
34	1985	30-33
35	25822	FUEL?
36	1726	30-35
37	169	35*30
38	3512	PROPULSION?
39	86	38*30
40	75774	ENERG?
41	155	30*40
42	33476	TECHNOLOG?
43	208	30*42
44	37549	EFFICIEN?
45	116	30*44
46	485	45+43+41+39
47	1410	30-46
48	29528	INSTRUMENT?
49	7	ANTI(W)ICE?
50	15923	FAILURE?

DIALOG File8: COMPENDEX 70-80/MAR (Copr. Engineering Index Inc.)
(Continued)

Set	Items	Description
51	5654	AGRICULTUR?
52	12992	SPECTROSCOP?
53	143497	MEASUR?
54	5218	METEOR?
55	1604	AIRPORT?
56	14035	BUILDING?
57	3016	REPAIR?
58	1528	LANDING?
59	42	THRUST(W)REVERS?
60	205475	48+49+50+51+52+53+54+55+56+57+58
61	1273	30-60
62	1134	36-60
63	63	39-60
64	106	41-60
65	159	43-60
66	99	45-60
67	139	37-60
68	31	63-(64+65+66+67)
69	51	64-(63+65+66+67)
70	112	65-(63+64+66+67)
71	79	67-(63+64+65+66)
72	65	66-(63+64+65+67)
73	875	62-(68+69+70+71+72)

Print 68/5/1-31
Print 69/5/1-51
Print 70/5/1-112
Print 71/5/1-79
Print 72/5/1-65

COMPREHENSIVE DISSERTATION QUERY SERVICE

KEYWORDS USED IN QUERY:
ADVANCED, ENERGY, EFFICIENT
AFTERBURNER
AFTERBURNERS
AIR, COOLED, BLADE
AIR, COOLED, BLADES
AIRCRAFT, PROPULSION
AIRCRAFT, METHANE
AIRCRAFT, ALCOHOL
AIRCRAFT, METHYL
AIRCRAFT, ETHYL
AIRCRAFT, DESIGN
AIRCRAFT, OPERATION
AIRCRAFT, OPERATIONS
AIRCRAFT, HYDROGEN
AIRCRAFT, THRUST
AIRCRAFT, PROPULSION
AIRCRAFT, FUEL
AIRCRAFT, FUELS
AIRCRAFT, ENGINE
AIRCRAFT, ENGINES
AIRPLANE, PROPULSION
AIRPLANE, METHANE
AIRPLANE, ALCOHOL
AIRPLANE, METHYL
AIRPLANE, ETHYL
AIRPLANES, METHANE
AIRPLANES, ALCOHOL
AIRPLANES, METHYL
AIRPLANES, ETHYL
AIRPLANE, DESIGN
AIRPLANE, OPERATION
AIRPLANE, OPERATIONS
AIRPLANE, HYDROGEN
AIRPLANES, HYDROGEN
AIRPLANES, PROPULSION
ASPIRATED, TURBINE, BLADE
ASPIRATED, TURBINE, BLADES
BORON, AIRCRAFT
BORON, AIRPLANE
BORON, AIRPLANES
BORON, FUELS
BORON, FUEL
COMBUSTION, ENGINES
COMBUSTION, ENGINE
DUCTED, FAN, ENGINE
DUCTED, FAN, ENGINES
ENGINE, ROCKET
ENGINE, ROCKETS

COMPREHENSIVE DISSERTATION QUERY SERVICE

KEYWORDS USED IN QUERY: (Continued)

FAN, JET
FLIGHT, PROPULSION
FUEL, ALCOHOL
FUEL, CONSERVATION
FUEL, ETHYL
FUEL, METHANE
FUEL, METHYL
FUEL, PROPULSION
FUELS, ALCOHOL
FUELS, ETHYL
FUELS, METHANE
FUELS, METHYL
FUELS, PROPULSION
GAS, TURBINES
GAS, TURBINE
HEAT, ENGINEERING
HIGH, TEMPERATURE, MATERIAL
HIGH, TEMPERATURE, MATERIALS
HYDROGEN, FUEL
HYDROGEN, FUELS
JET, ENGINE
JET, ENGINES
LIQUID, PROPELLANTS
LIQUID, PROPELLANT
MAGNITO, HYDRODYNAMICS
MAGNITO, HYDRO, DYNAMICS
MAGNITOHYDRODYNAMICS
MHD
NON, FOSSIL, FUEL
NON, FOSSIL, FUELS
PLASMA, THRUST
PLASMA, ENGINE
PLASMA, ENGINES
PROPULSION, SYSTEM
PROPULSION, SYSTEMS
RAM, JET
REHEAT, CYCLE
REHEAT, CYCLES
ROCKET, MOTOR
ROTARY, ENGINES
ROTARY, ENGINE
SOLAR, ENGINE
SOLAR, ENGINES
SOLID, PROPELLENTS
SOLID, PROPELLENT
THERMAL, ENGINES
THERMAL, ENGINE
THERMAL, CYCLES
THERMAL, CYCLE

COMPREHENSIVE DISSERTATION QUERY SERVICE

KEYWORDS USED IN QUERY: (Continued)
THRUST AUGMENTATION
TURBO, JET
TURBO, JETS
TURBO, PROPS
TURBO, PROP
WANKEL, ENGINE
WANKEL, ENGINES

DOE

SET HISTORY

SET	DESCRIPTOR	CITS
1	IT=SYNTHETIC FUELS	5529
2	IT=HYDROGEN FUELS	924
3	IT=SOLID FUELS	586
4	IT=SHALE OIL	2151
5	1+2+3+4	6105
6	IT=PROPELLANTS	341
7	IT=PROPULSIONS	566
8	IT=AIRCRAFT	1516
9	IT=AIR TRANSPORT	179
10	6+7	890
11	8+9	1606
12	5*9*10	
13	5*10*11	7
14	5*10	127
15	5*11	155
16	14*15	7
17	13-13	
18	14-13	120

DTIC

SEARCH CONTROL NUMBER ERL002

SEARCH STRATEGY

The terms below were searched by the computer. Asterisk terms represent weighted retrieval terms. Truncated retrieval terms indicate that all terms with the depicted root have been searched. Coordinate searches are portrayed as search terms listed on various levels. Excluded retrieval terms are displayed under an exclude listing.

FIRST LEVEL SEARCH TERMS
- AIRCRAFT
- AVIATION

SECOND LEVEL SEARCH TERMS

OPERATION	(TRUNCATED)
STRATEGIC	(TRUNCATED)
SYSTEM	(TRUNCATED)
WARFARE	(TRUNCATED)

DTIC

SEARCH CONTROL NUMBER ERL001

SEARCH STRATEGY

The terms below were searched by the computer. Asterisk terms represent weighted retrieval terms. Truncated retrieval terms indicate that all terms with the depicted root have been searched. Coordinate searches are portrayed as search terms listed on various levels. Excluded retrieval terms are displayed under an exclude listing.

FIRST LEVEL SEARCH TERMS	
AIRCRAFT	(TRUNCATED)
SECOND LEVEL SEARCH TERMS	
ALTERNATE	(TRUNCATED)
APPLICATION	(TRUNCATED)
CONFIGURATION	(TRUNCATED)
DESIGN	
FEASIBILITY	(TRUNCATED)
POTENTIAL	(TRUNCATED)
PROSPECT	(TRUNCATED)
STATUS	
TECHNOLOGY	(TRUNCATED)

DTIC

SEARCH CONTROL NUMBER ERL003

SEARCH STRATEGY

The terms below were searched by the computer. Asterisk terms represent weighted retrieval terms. Truncated retrieval terms indicate that all terms with the depicted root have been searched. Coordinate searches are portrayed as search terms listed on various levels. Excluded retrieval terms are displayed under an exclude listing.

FIRST LEVEL SEARCH TERMS
- AIRCRAFT
- AVIATION

SECOND LEVEL SEARCH TERMS

CONSERVATION	(TRUNCATED)
ENERGY	(TRUNCATED)
FUEL	(TRUNCATED)

DTIC

SEARCH CONTROL NUMBER 092996

SEARCH STRATEGY

The terms below were searched by the computer. Asterisk terms represent weighted retrieval terms. Truncated retrieval terms indicate that all terms with the depicted root have been searched. Coordinate searches are portrayed as search terms listed on various levels. Excluded retrieval terms are displayed under an exclude listing.

FIRST LEVEL SEARCH TERMS
* AEROSPACE CRAFT
* AEROSPACE PLANES
* AIR CUSHION VEHICLES
* AIR SUPERIORITY FIGHTERS
AIR VEHICLES
* AIRCRAFT
AIRCRAFT ENGINES
* AIRPLANES
* AIRSHIPS
* ALL WING PLANES
* AMPHIBIOUS AIRCRAFT
* ANTISUBMARINE AIRCRAFT
* ARMY AIRCRAFT
* ATTACK AIRCRAFT
* ATTACK BOMBERS
* ATTACK HELICOPTERS
* AUTOGYROS
AVIATION
* BALLOONS
* BOMBER AIRCRAFT
* BOOST GLIDE VEHICLES
* CAPTIVE AIRSPACE CRAFT
* CARRIER BASED AIRCRAFT
* COMMERCIAL AIRCRAFT
* COMPOSITE PLANES
* CONVERTIBLE PLANES
* DOWNED AIRCRAFT
* DRONE CONTROL PLANES
* DRONES
* ELECTRONIC AIRCRAFT
* FIGHTER AIRCRAFT

DTIC

SEARCH CONTROL NUMBER 092996 (Continued)

FIRST LEVEL SEARCH TERMS
* FIGHTER BOMBERS
* FIXED WING AIRCRAFT
* FLYING BOATS
* FLYING PLATFORMS
* GLIDERS
* GROUND EFFECT MACHINES
* GUNSHIPS
* HELICOPTERS
* HYPERSONIC AIRCRAFT
* JET AIRCRAFT
* JET BOMBERS
* JET FIGHTERS
* JET FLYING BOATS
* JET SEAPLANES
* JET TRAINING PLANES
* JET TRANSPORT PLANES
* METEOROLOGICAL BALLOONS
* MILITARY AIRCRAFT
* NAVAL AIRCRAFT
* OBSERVATION AIRCRAFT
* PARASITE PLANES
* PASSENGER AIRCRAFT
* PATROL AIRCRAFT
* POWERED BALLOONS
* RECONNAISSANCE AIRCRAFT
* REMOTELY PILOTED VEHICLES
* RESEARCH AIRCRAFT
* RESEARCH PLANES
* ROCKET PLANES
* ROTARY WING AIRCRAFT
* SEAPLANES
* SHORT TAKEOFF AIRCRAFT
* SUPERSONIC AIRCRAFT
* SUPERSONIC TRANSPORTS
* SURVEILLANCE DRONES
* TACTICAL AIRCRAFT
* TAILLESS PLANES
* TANKER PLANES
* TARGET DRONES
* TOWED PLANES
* TOWING PLANES
* TRAINING PLANES
* TRANSONIC AIRCRAFT
* TRANSPORT AIRCRAFT
* UTILITY AIRCRAFT
* VARIABLE STABILITY AIRCRAFT
* VERTICAL TAKEOFF AIRCRAFT
* WATER BASED PLANES
* WEATHER RECONNAISSANCE AIRCRAFT

DTIC

SEARCH CONTROL NUMBER 092996 (Continued)

SECOND LEVEL SEARCH TERMS

ALTERNATIVE FUEL	(TRUNCATED)
EXOTIC FUEL	(TRUNCATED)
HYDROGEN FUEL	(TRUNCATED)
LIQUID HYDROGEN	(TRUNCATED)
PROPELLANTS	
SYNTHETIC FUEL	(TRUNCATED)

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KEYWORDS

AEROPLANES-ROCKET ENGINES
AIRCRAFT ENGINES AND GAS TURBINES
AIRCRAFT FUEL EFFICIENCY PROGRAM
AIRCRAFT INDUSTRY

ALCOHOL AS FUEL

AVIATION AND SPACE: PROGRESS AND PROSPECTS
AVIATION FUEL CONSERVATION RESEARCH & DEVELOPMENT
AVIATION FUELS
AVIATION INDUSTRIES PROFILES AND ENER.
AVIATION TECHNOLOGY SERIES

CHEMICAL ENERGY

COAL AND ENERGY
COAL AS AN ENERGY RESOURCE
COAL COMBUSTION
COAL CONVERSION TECHNOLOGY
COAL LIQUEFACTION
COAL LIQUIFICATION

ELECTRIC PROPULSION SYSTEMS
ELECTRIC ROCKET ENGINES

ENERGY AND ENGINES
ENERGY CONVERSION ENGINEERING
ENERGY FROM OIL SHALE
ENERGY FROM SOLID WASTE
ENERGY FROM SOLID WASTES
ENERGY FROM SOLID WASTE UTILIZATION
ENERGY PRINCIPLES IN STRUCTURAL MECHANICS
ENERGY PRINCIPLES IN THEORY OF STRUCTURE
ENERGY PRODUCTION & THERMAL EFFECTS
ENERGY PROSPECTS TO 1985
ENERGY R&D
ENERGY R&D AND NATIONAL PROGRESS
ENERGY TECHNOLOGY
ENERGY UTILIZATION AND THE DESIGN PROFESSION

FUEL CELLS

HYDROGEN AS FUEL

LIQUID FUELS
LIQUID PROPELLANTS

MAGNETOHYDRODYNAMIC GENERATORS
MAGNETOHYDRODYNAMICS

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KEYWORDS (Continued)
METHANE
METHANOL

NUCLEAR ROCKETS

OIL SHALE TECHNOLOGIES
OIL SHALE TECHNOLOGY

PETROLEUM, SYNTHETIC

PLASMA (IONIZED GASES)

POWER RESOURCES

REFUSE AS FUEL

ROCKET ENGINES--FUEL SYSTEMS
ROCKET PROPULSION; ROCKET PROPULSION ELEMENTS
ROCKET PROPULSION AND SPACEFLIGHT DYNAMICS
ROCKET PROPULSION ELEMENTS
ROCKETRY
ROCKETS (AERONAUTICS)

SHALE OIL, TAR SANDS, AND RELATED FUEL
SHALE OILS

SOLAR ENGINES

SOLID PROPELLANTS

SPACE VEHICLES-PROPULSION SYSTEMS
SPACE VEHICLES-SOLAR ENGINES

SYNTHETIC FUEL
SYNTHETIC FUEL INDUSTRY
SYNTHETHC FUELS
SYNTHETIC FUELS INDUSTRY
SYNTHETIC FUELS PROCESSING

BIBLIO FILE

KEYWORDS
AERONAUTICAL RESEARCH
AEROSPACE CORPORATION ENERGY AND TRANSPOR.
AIRCRAFT
AVIATION FUELS
AVIONICS

BIBLIO FILE

KEYWORDS (Continued)

COAL GASIFACTION
COAL GASIFICATION
COAL LIQUEFACTION
FUEL
FUEL CELLS
FUEL RESEARCH
HYDROGEN AS FUEL
MAGNETO HYDRODYNAMICS
METHANE
METHANOL

NASA LITERATURE SEARCH

FUELS AND ENERGY CONSERVATION LIMITED TO AVIATION AND AIRCRAFT

SCOPE: Comprehensive search with broad coverage including related references.

PERIOD: 1973 to date shown above.

NUMBER OF CITATIONS: Machine Search - 251

SET NO.		DESCRIPTION
1	3148	ST/ENERGY CONSERVATION
2	25217	UTP/ENERGY
3	1599	E14-E16, E8-E13 UTP/CONS
4	789	2*3
5	3275	1+4
6	2203	E7, E17 UTP/FUEL
7	6	3*6
8	51	NOC/ENERGY *+1 CONSERVA
9	698	AX/ENERGY *+1 CONSERVAT
10	3537	5+7+8+9
11	8119	ST/AIRCRAFT DESIGN
12	4835	ST/AIRCRAFT ENGINES
13	452	ST/AIRCRAFT FUEL SYSTEM
14	824	ST/AIRCRAFT FUELS
15	373	ST/AIRCRAFT HYDRAULICS
16	1252	ST/AIRCRAFT MODELS
17	719	ST/AIRCRAFT PARTS
18	368	ST/AIRCRAFT SPECIFICATION
19	4400	ST/AIRCRAFT STRUCTURES
20	18788	UTP/AIRCRAFT
21	3074	RT/AERODYNAMICS
22	637	US/AERONAUTICS
23	3179	RT/CIVIL AVIATION
24	3837	R7, R6, R8 ST/CIVIL AVIATION
25	713	ST/LIGHT AIRCRAFT
26	3971	R54, R56, R59, R61, R55 ST/
27	3766	R62-R66 ST/LIGHT AIRCRAFT
28	32404	11+12+13+14+15+16+17+18
29	16409	21+22+23+24+25+26+27
30	294	10*(28+29)
31	3023	MJ/ENERGY CONVERSION EF
32	1708	MJ/ENERGY CONSERVATION
33	4861	31+32+4+7
34	183	33*(28+29)
35	545	MJ/AIRCRAFT FUELS
36	41	35*10
37	4277	MJ/ENERGY TECHNOLOGY
38	36	37*(28+29)

NUMBER OF
CITATIONS: Machine Search -251 (Continued)

SET NO.			DESCRIPTION
39	5	8	35*37
40	231	319	34+36+38+39
41	12	12	UTP/ALTERNATIVE *+1 FUEL
42	50	50	UTP/ALTERNATIVE *+1 FUEL
43	13	28	(28+29)*(41+42)
44	2282	2282	MJ/COST EFFECTIVENESS
45	14	14	14*44
46	249	350	40+43+45
47	753	753	MJ/JET ENGINE FUELS
48	10	12	(33+37)*47
49	251	354	46+48
50	251	354	)49/73-80
51	247	349	)50/73-80/A,B,N,K,W,M
52	4	5	)50/73-80/X

NASA LITERATURE SEARCH

TECHNOLOGIES, STUDIES, AND RESEARCH ON NEW AIR VEHICLES
EXCLUDING PETROLEUM BASED ENERGY FOR PROPULSION

SCOPE: Comprehensive search with broad coverage including forecasting for the years 1980-2000.

PERIOD: 1970 to date shown above.

NUMBER OF
CITATIONS: Machine Search - 220

SET NO.		DESCRIPTION
1	2837	ST/AIR TRANSPORTATION
2	3013	ST/TRANSPORT AIRCRAFT
3	663	ST/SHORT HAUL AIRCRAFT
4	93	ST/NATIONAL AVIATION SY
5	3532	ST/AIRCRAFT CONTROL
6	7865	ST/AIRCRAFT DESIGN
7	4688	ST/AIRCRAFT ENGINES
8	435	ST/AIRCRAFT FUEL SYSTEM
9	358	ST/AIRCRAFT HYDRAULIC S
10	1217	ST/AIRCRAFT MODELS
11	700	ST/AIRCRAFT PARTS
12	3848	ST/AIRCRAFT PERFORMANCE
13	4178	ST/AIRCRAFT STRUCTURES
14	18319	UTP/AIRCRAFT
15	102	UTP/AIR *+1 VEHICLE
16	42	UTP/AIR *+1 VEHICLES
17	144	15+16
18	466	ST/AIRSHIPS
19	38290	1+2+3+4+5+6+7+8+9+10+11
20	9113	E7-E17 ST/FUEL
21	6500	E18-E29 ST/FUEL
22	6514	R3-R18 ST/FUELS
23	7548	R19-R36 ST/FUELS
24	8000	R37-R44 ST/FUELS
25	1952	RT/LIQUID HYDROGEN
26	528	RT/SHALE OIL
27	1196	ST/FUEL SYSTEMS
28	505	ST/TRANSPORTATION ENERG
29	1196	ST/FUEL SYSTEMS
30	93	BT/CHEMICAL FUELS
31	1020	RT/HYDROCARBON FUELS
32	1082	RT/JET ENGINE FUELS
33	2675	RT/LIQUID ROCKET PROPEL
34	571	RT/MONOPROPELLANTS
35	158	RT/SLURRY PROPELLANTS
36	32715	20+21+22+23+24+25+26+27

NUMBER OF
CITATIONS: Machine Search -220 (Continued)

SET NO.			DESCRIPTION
37	1044	1064	14*36
38	1049	1049	ST/FOSSIL FUELS
39	1049	1060	37-38
40	628	643	UTP/PETROLEUM
41	57	59	UTP/CRUDE *+1 OIL
42	15	16	UTP/CRUDE *+1 OILS
43	628	643	UTP/PETROLEUM
44	254	313	AX/CRUDE *+1 OIL
45	37	46	AX/CRUDE *+1 OILS
46	1024	1349	TX/PETROLEUM
47	1672	2427	40+41+42+43+44+45+46
48	1019	1038	39-47
49	444	448	UTP/2000
50	2140	2360	TX/2000
51	131	131	UTP/1980 *+1 S
52	6	12	48*(49+50+51)
53	21	48	39*47
54	9138	9173	UTP/FUTURE
55	10572	11756	TX/FUTURE
56	1	1	UTP/NONPETROLEUM
57	16	19	TX/NONPETROLEUM
58	2293	2886	19*(27+20+21+22+23+24+2
59	203	539	58*(54+55)
60	46110	46664	UTP/STUDY
61	17971	18139	UTP/STUDIES
62	12173	12690	UTP/TECHNOLOGY
63	498	503	UTP/TECHNOLOGIES
64	2334	2930	19*36
65	2322	2916	64-38
66	16	37	65*(49+50+51)
67	82	190	65*54
68	236	559	65*(60+61+62+63)
69	797	797	ST/AIRCRAFT FUELS
70	435	435	ST/AIRCRAFT FUEL SYSTEM
71	52	132	68*(69+70)
72	30	61	39*54
73	16	36	99*99
74	44	95	72+73
75	17	20	56+57
76	3	6	75*(69+70)
77	501	501	MJ/SYNTHETIC FUELS
78	19	19	UTP/ALTERNATE *+1 FUELS
79	81	83	UTP/SYNTHETIC *+1 FUELS
80	31	31	UTP/SYNTHETIC *+1 FUEL
81	22383	37499	TX/AIRCRAFT

NUMBER OF
CITATIONS: Machine Search - 220 (Continued)

SET NO			DESCRIPTION
82	18319	18688	UTP/AIRCRAFT
83	525	525	MJ/AIRCRAFT FUELS
84	40	90	(81+82+83)*(77+78+79+80
85	13	13	99*99
86	185	450	74+71+67+76+84+85
87	2275	2327	UTP/FORECAST//FORECASTS
88	7661	7944	UTP/FUEL //FUELMOVE
89	9	31	(54+87)*88*82
90	174	422	86-99
91	193	441	90+99
92	25	25	99*99
93	175	423	91-99
94	160	385	)93//A,B,N,K,W,M
95	15	38	)93//X

NASA LITERATURE SEARCH

PROPULSION OF AIR VEHICLES EXCLUDING PETROLEUM

SCOPE: References pertinent to the above subject.

PERIOD: 1970 to date shown above.

NUMBER OF
CITATIONS: Machine Search - 157

SET NO.		DESCRIPTION
1	4	4 ST/LASER PROPULSION
2	1130	1130 ST/ELECTRIC PROPULSION
3	93	93 ST/ELECTROMAGNETIC PROPULSION
4	138	138 ST/ELECTROSTATIC PROPULSION
5	565	565 ST/ION PROPULSION
6	117	117 ST/NUCLEAR ELECTRIC PROPULSION
7	381	381 ST/LOW THRUST PROPULSION
8	362	362 ST/CHEMICAL PROPULSION
9	1007	1007 ST/NUCLEAR PROPULSION
10	3374	3374 1+2+3+4+5+6+7+8+9
11	4701	4701 ST/AIRCRAFT ENGINES
12	18390	18759 UTP/AIRCRAFT
13	93	95 10*(11+12)
14	22552	37796 TX/AIRCRAFT
15	23	53 10*14
16	104	148 13+15
17	19	19 UTP/ALTERNATE *+1 FUELS
18	1957	1957 ST/LIQUID HYDROGEN
19	1066	1066 ST/HYDROGEN FUELS
20	7899	7899 ST/AIRCRAFT DESIGN
21	436	436 ST/AIRCRAFT FUEL SYSTEM
22	798	798 ST/AIRCRAFT FUELS
23	358	358 ST/AIRCRAFT HYDRAULIC S
24	9285	9285 20+21+22+23
25	2877	2877 17+18+19
26	163	163 24*25
27	73	117 10*(12+14+20+21+22+23)
28	274	321 13+26+27
29	255	302)28/70-80
30	113	159 16+27
31	99	145)30/70-80
32	3072	3072 ST/NUCLEAR FUELS
33	556	556 ST/NUCLEAR ELECTRIC POW
34	103	103 ST/NUCLEAR PROPELLED AI
35	1007	1007 ST/NUCLEAR PROPULSION
36	4591	4591 32+33+34+35
37	147	205 36*(12+11+14+20)
38	157	225 31+37
39	141	209)38/70-80

NUMBER OF
CITATIONS: Machine Search - 157 (Continued)

SET	NO.		DESCRIPTION
40	52	63	)38/70-80
41	16	60	(11+12+14+20)*40
42	157	269	39+41
43	157	269	)42/70-80
44	142	252	)43//A,B,N,K,W,M
45	15	17	)43//X

NTIS

TITLE: Aircraft Propulsion Using Nonpetroleum Fuels

Strategy: - General guidance and suggested key words.
Searcher strategy not available.

TITLE: Advanced Aircraft Design

Strategy: -

Non-fossil aircraft fuels such as hydrogen, alcohol, methane, boron, and rocket fuels as used in non-air-breathing propulsion units.

Aircraft engine and/or propulsion system improvements or variations such as increased temperatures, compression ratios, component efficiencies, specific fuel consumption, materials improvements (strength to weight ratio and high temperature capability); cycle and/or geometry variations; plasma and/or magnetohydrodynamic propulsive units; aspirated or air-cooled turbine blades.

Aircraft geometry innovations to reduce drag and airplane wieght, improve lift to drag ratio and convert solar energy to electrical or mechanical (propulsive) form.

NTIS (DIALOG)

SET	ITEMS	DESCRIPTION
1	0	(BYPASSED) EXECUTE3W7Z
2	28697	AIRCRAFT?
3	91745	ENERG?
4	6104	CONSERV?
5	48147	TECHNOL?
6	153102	SYSTEM?
7	58487	DESIGN?
8	5598	CONCEPT?
9	10956	CONFIG?
10	12107	FEASIB?
11	4037	ALTERN?
12	2103	2*5
13	9816	2*6
14	4708	2*7
15	534	2*8
16	2055	2*9
17	135	2*11
18	753	2*3
19	3477	4*3
20	31360	8+9+10+11
21	94372	3+4
22	134689	3+5
23	15199	12+13+14+15+16+17+18
24	765	23*21
25	3063	23*20
26	3477	3*4
27	5203	3*5
28	2767	23*22
29	101	23*26
30	89	23*27
31	163	29+30
32	5500	17+24+25+28
33	2438	OTHER?
34	59	2*33
35	15236	23+34
36	765	35*21
37	3063	35*20
38	2767	35*22
39	101	35*26
40	89	35*27
41	5500	17+36+37+38
42	0	41+32
43	5500	17+36+37+38
44	5551	32+34
45	0	PY=75
46	0	YR=75
47	0	1/A67152G2-A7185H1
48	0	1/C3824H1-C5571B4

NTIS (DIALOG) (Continued)

SET	ITEMS	DESCRIPTION
49	0	LIMIT 1/A6715G2-A7185H1
50	0	1/F0011A2-F2481C1
51	0	1/F0011A2-F2481C1
52	2577	44/A6715G2-D9991A1
53	22008	CF=21
54	11106	CF=81
55	22546	53+54
56	362	52*55
57	2215	52-56
58	746	44*55
59	2823	31+28+34+40
60	895	31+58+34+40

Prints: 895

* EITHER WORD USED
\+ DELETE DUPLICATION

SSIE

TITLE: Aircraft/Air Vehicles/Aviation Utilizing Propulsion Methods or Technology Not Dependent on Petroleum Derived Energy.

Strategy: General guidance and suggested key words.

Seacher strategy not available.

SSIE (DIALOG)

SET	ITEMS	DESCRIPTION
1	1383	SERIAL# 3W7Z
2	4244	AIRCRAFT?
3	18233	ENERG?
4	3267	CONSERV?
5	16457	TECHNOL?
6	77126	SYSTEM?
7	24163	DESIGN?
8	6147	CONCEPT?
9	4564	CONFIG?
10	5580	FEASIB?
11	5867	ALTERN?
12	1047	2*5
13	2475	2*6
14	1731	2*7
15	540	2*8
16	633	2*9
17	159	2*11
18	671	2*3
19	1490	4*3
20	19860	8+9+10+11
21	20010	3+4
22	31085	3+5
23	3569	12+13+14+15+16+17+18
24	723	23*21
25	1316	23*20
26	1490	3*4
27	3605	3*5
28	1549	23*22
29	55	23*26
30	169	23*27
31	196	29+30
32	2311	17+24+25+28
33	88853	OTHER?
34	3143	2*33
35	3964	23+34
36	733	35*21
37	1334	35*20
38	1549	35*22
39	55	35*26
40	169	35*27
41	2338	17+36+37+38
42	27	41-32
43	2338	17+36+37+38

Print: 32/5/1-2311
Print: 42/5/1-27

Prints: 2338

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