

**Crisis Management Demonstration and Development
Facility (CM/DDF): Final Technical Report**

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**Technical Report
CCA-80-14
December, 1980**

Lynn Brock

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1. Abstract

This document reports on the successful establishment of a Crisis Management Development and Demonstration Facility (DDF) in support of the ARPA-CTO Crisis Management Program. The Facility assisted the Crisis Management Program in developing software aids for crisis management, and demonstrated those aids to potential DOD users. The DDF also facilitated the transfer of those products from the research environment into operational service.

Specifically, the Crisis Management Development and Demonstration Facility provided five types of services:

- A. Timesharing computer services to Crisis Management Program personnel and contractors.
- B. Assistance to the Crisis Management Program in selection and acquisition of state-of-the-art technologies for installation in the facility.
- C. Assistance to Crisis Management Program researchers in using the Facility, in converting applications software to run on the Facility's computer system,

and in computer-system aspects of creating new software products.

D. Demonstrations of software products developed at the DDF to potential users of the products.

E. A product distribution service in which developed software products were packaged and distributed to operational users.

This report discusses the three phases of the DDF life cycle:

Phase I: Procurement and installation of a hardware configuration at the site, together with initial software installation.

Phase II: Operation of the timesharing system, and the development and demonstration of the database and related software.

Phase III: Completion of system software acquisition and the development of application software.

2. Introduction

In 1977, CCA established a Crisis Management Development and Demonstration Facility (DDF) to support the efforts of the ARPA-CTO Crisis Management Program. In general, the Facility provided timesharing computer services for the development of automated aids to crisis management, including crisis forecasting systems and computer-based aids for crisis managers. Also, the Facility served as a focus for the ARPA-CTO in crisis management, and helped ARPA-CTO-CMP management to guide contractors in important new directions. Finally, the Facility functioned as a distribution center for crisis management products, in addition to affording a convenient and attractive locale for demonstrating those products.

The life cycle of the DDF involved three phases:

Phase I - CCA prepared the physical site for the Facility, and acquired, installed, and checked out the initial computer hardware.

The Facility demanded a physical site which would contribute to its dual role as a capabilities demonstration center and a provider of computer services. For example, the site called for environmental control features such as air conditioning, workspace for

CMP contractors and office space for CCA personnel, as well as an attractive demonstration area for groups of ten to fifteen visitors.

The hardware obtained during Phase I consisted of the central processor, a core memory, a console terminal, and a magnetic tape unit. This hardware was later expanded to include a disk storage unit, a printer/plotter, and communications gear (such as terminal interfaces, modems, graphics, alpha-numeric terminals, and an Arpanet interface).

Phase II - With the acquisition and installation of this additional computer hardware CCA began operating the Facility. During the second phase, CCA maintained and operated the Facility's hardware and software, installed and documented crisis management software and databases, provided user support to crisis management contractors, and conducted demonstrations of crisis management products.

The configuration of hardware during Phase II proved adequate for DDF computation needs projected for FY 78 and FY 79. However, this configuration was planned for further expansion to accommodate anticipated DDF growth. For example, under the direction of ARPA-CTO-CMP management, CCA procured, installed,

and interfaced innovative hardware and software items that ARPA-CTO-CMP wished its contractors to use.

During Phase II, the DDF Facility operated as a service to the Crisis Management Program. It provided a unified computer environment for its contractors, freeing them from concerns of computer-related details that were irrelevant to their endeavors. The Facility also permitted comprehensive demonstrations of developed crisis management products, with minimum disruption of contractor activities. Third, the Facility served CMP management as a vehicle for introducing new computer technologies into the program, thus making them available to all contractors.

Phase III - The Facility continued to operate as it had during Phase II, but placed greater emphasis on demonstrating and transferring products to operational DOD users. CCA conducted many more demonstrations. Also, CCA personnel packaged and documented crisis management products in cooperation with the developer of each product, and distributed products to DOD users.

In particular, during Phase III the DDF expanded from a service for developing products into a center for demonstrating and supplying the crisis management

products that ARPA developed to operational DOD personnel.

This report examines the accomplishments of all three phases. Section 3 supplies some background information concerning the development of a Crisis Management DDF and the roles it played. Section 4 and its subsections treat the DDF and its development phases in detail. Section 5 presents some general conclusions regarding the DDF.

3. Background

Over the past several years, the field of quantitative international politics has evolved from a field of purely basic research to one with more applied activities. The ARPA Crisis Management Program similarly evolved in its capacity to develop products that could provide crisis management assistance in an operational setting. These products include databases, interactive software, and predictive algorithms.

Together with increased capabilities in applied crisis management, operational personnel showed increasing interest in, and demand for, crisis management tools. Based on the state-of-the-art at the time, it was expected that these tools could be developed and transferred to national and theater level commands within a few years.

However, the number of crisis management tools that were actually able to be developed and demonstrated outgrew the computer resources available for their development within the Crisis Management Program. Most Crisis Management contractors were developing their software on commercial timesharing services. Not only did this practice create huge expenses but it also led to software products incompatible with each other, and incapable of being

distributed to external users without major software conversion efforts.

Furthermore, there existed no convenient means within such a fragmentary arrangement for ARPA to guide its CMP contractors in innovative directions. As new technologies emerged that CMP might exploit, it became necessary for ARPA to provide each contractor with an individual copy of the hardware or software mechanisms, resulting in different conversion problems at each site. Even if all these problems had been overcome, it would have been difficult for the CMP management to ensure maximum utilization of new ideas and technology by each contractor.

The DDF addressed these problems by providing a central computer facility for developing, demonstrating, and then transferring crisis management software and databases. This facility enabled multiple users to develop software, maintain databases, conduct statistical analyses, and demonstrate various products.

The Facility allowed new hardware and software technologies to be installed there and made available to all contractors inexpensively and uniformly. CMP management could correct errors in one location and make a single version of the revised software available to all contractors.

By providing identical sophisticated resources to all contractors, CTO could guide them more easily in the general directions required for overall program goals. For example, if the Facility needed improved interactive graphics, it could supply better graphics software; if CTO perceived a need for better statistical analysis tools, the Facility could obtain and install state-of-the-art statistical packages. As new hardware devices became available and relevant to CMP objectives (for example, digitizers, color and dynamic displays), the hardware could be installed within the Facility and all contractors urged to exploit it in their research and development.

Thus, the DDF simultaneously filled a range of beneficial roles within the Crisis Management Program:

It provided a timesharing service to CMP contractors that both responded to their needs and cost less than commercial services.

It provided CMP management with a convenient means of directing the computer-oriented R&D of its contractors.

It facilitated the economical acquisition of hardware

and software and the effective utilization of these items by contractors.

It encouraged the sharing of ideas, data, and algorithms among CMP contractors.

It facilitated the integrated demonstration of CMP products to operational DOD users, and the subsequent transfer of these products into operational settings.

The next section describes the activities, the physical site, and the hardware and software configuration of the DDF in greater detail.

4. Description of DDF

This section describes the Crisis Management Development and Demonstration Facility. The description is organized as follows:

- A. Section 4.1 describes the accomplishments of Phase I, including its hardware and software configurations.
- B. Section 4.2 details the results of Phase II, including the timesharing and database management systems.
- C. Section 4.3 summarizes the accomplishments of Phase III, including installed system and application software.

Before proceeding to the detailed discussion of the Facility, the present section offers a brief overview of it.

The Crisis Management and Demonstration Facility was located at 1600 Wilson Boulevard in the Rosslyn section of Arlington, Virginia.

The physical DDF site served both as a computer installation and as a demonstration area for displaying computer-

based products of the Crisis Management Program. The Facility also housed office space for CCA personnel assigned to the Facility and workspace for CMP contractors.

The activities of the Facility during its life cycle evolved through three phases, as described above. Early efforts--Phase I--had the goal of preparing the Facility's physical sites, both its computer room and its demonstration/work area. During Phase II, the DDF functioned as a computation resource in support of Crisis Management Program R&D. Operation of the Facility continued throughout Phase III with the demonstration of products developed by CMP contractors at the Facility, and their ultimate distribution to operational DOD users.

The DDF acquired virtually all of the necessary hardware during Phase I. The facility obtained a PDP-11/70 system with mainframe, peripherals, communications equipment, and sophisticated user interface peripherals (for example, interactive graphics and a printer/plotter). The hardware configuration supplied sufficient computing power and storage capacity to support CMP usage. The communications equipment permitted access to the computer system either locally (that is, from within the Center itself) or remotely (from both the Washington area and greater distances).

As originally designed, the Center's hardware configuration would accommodate usage projected through FY79, but would also allow expansion in many directions as future needs dictated. More memory, more communication lines, and more peripherals could all be added to the system as required. A particularly important consideration in this regard was the likelihood that new state-of-the-art devices would be added to the Center during its life cycle as CMP research and development advanced toward an optimum analyst/computer environment. This environment did in fact evolve during the course of the CM/DDF effort and was supported by the acquisition of dynamic and color display terminals and digitizing devices. Section 4.1.2 contains a complete description of this configuration.

In addition to the above system software, the DDF included crisis management application software and databases. CMP management selected the specific items to be supported in this category. Such items included DDI's Interactive Crisis Early Warning Prototype System [WITTMAYER] and variations of it [DDI], as well as databases including WEIS, WARP, and an assortment of research data sets. Section 4.3 further describes software for the DDF.

4.1 Accomplishments of Phase I

Phase I of the CM-DDF was devoted to preparatory activities: preparation of the Facility's physical site, and acquisition of necessary computer hardware and software.

Phase I ran from 1 June 1977 to 31 October 1977, and proved a resounding success. Its accomplishments exceeded the projections of the proposal for that period. Phase I saw the completion of all the activities necessary to prepare the CM-DDF, so that the Facility became ready for full-scale operations to begin in October 1977.

The key accomplishments of Phase I covered the areas of:

- site preparation
- hardware acquisition
- software acquisition

These are discussed in the following subsections.

4.1.1 Site Preparation

Preparations of the physical site reached completion during Phase I, as expected. The site included a computer room, a demonstration room, five offices to be used both by CM/DDF staff and visitors to the Facility, and a storage room (included principally to facilitate modest expansion of the site).

Cabling for terminals and graphics units was arranged so that users could operate any of the Facility's terminals or 4051 graphics units in any office or from any location around the demonstration room. This cabling ran through the walls like electrical power wiring to allow for flexibility of system operation and to preserve the physical appearance of the site.

The computer room was designed to permit reasonable expansion of the CM/DDF's computer system without requiring additional site remodeling. The room was physically large enough and had sufficient electrical power and air conditioning to make such expansion possible.

The Demonstration room accommodated demonstration audiences of 15 - 20 persons comfortably; cabling in the room allowed up to eight terminals and Tektronix 4051 graphics units to be operated in that area. The DDF site also

included five offices for the use of CM/DDF staff and visitors, including CM/DDF users at the site. Each office could contain up to two terminals or 4051s. Three of the five offices were used by the CM/DDF staff, the other two being reserved for CMP contractors working on-site.

The storage room included in the plan was intended for expansion purposes. As CM/DDF usage increased, the room could either add to the available office space or enlarge the size of the computer room.

4.1.2 Hardware Acquisition

During Phase I, the Facility acquired all of the computer hardware needed for operation. Indeed, hardware acquisition far surpassed the level originally projected for Phase I. This success resulted from the efforts of CMP management to obtain as government furnished equipment a complete basic PDP-11/70 system for the CM/DDF. CCA procured additional hardware during Phase I to augment the basic PDP-11/70 system and to bring it up to the capacity needed for Phase II operation of the Facility.

The hardware configuration of the CM/DDF computer system contained the major components listed below:

A. Processor and options

- a. PDP-11/70 processor
- b. FP11-C floating point arithmetic processor
- c. M9301-YC bootstrap/diagnostic ROM loader
- d. KW11-L line frequency clock
- e. KW11-P programmable clock
- f. LA36-C Decwriter-II operator's console
- g. DL11-A console terminal controller

B. Mainframe peripherals

- a. 512K bytes core memory.
- b. 100 Million bytes of disk storage, consisting of one RWP04-AA disk drive and controller (expandable to .7 billion bytes), and a dual RK11 disk drive controller (expandable to 19.2 million bytes).
- c. One TWU16-EA industry standard magnetic tape drive and controller, capable of 800 or 1600 BPI operation (expandable to 8 drives).

C. Human interface peripherals

- a. Two Tektronix 4051 Interactive Graphics Systems each with the following options:

Communication Interface and 4952-2 Joystick.

- b. One Tektronix 4631 hard-copy unit and one 4631-2 multiplexor.
- c. An LV11-BA electrostatic printer/plotter and controller.
- d. Assorted other terminals provided as GFE.

D. Communication equipment

- a. One DH11-AD 16 port terminal multiplexor with full modem control (expandable to 256 ports).
- b. Six Astrocom 130W2-4 modem cards, with automatic answer; these modems operate at 300 bps, full-duplex (Bell 103A compatible).
- c. Six Astrocom 120D1 modem cards, with automatic answer, and supervisory (reverse) channel; these modems operate at 120 bps, half-duplex over dial-up telephone lines (Bell 202C compatible).
- d. One rack to mount the above modems (items b and c) in a computer equipment bay (up to sixteen

modems may be mounted per rack).

- e. Five Anderson Jacobson A242 modems, originate only, with acoustic couplers, for 300 bps, full-duplex operation (Bell 103 compatible).
- f. Seven Anderson Jacobson ADAC 1200 modems, with acoustic coupler and supervisory (reverse) channel; these modems are capable of 1200 bps, half-duplex operation over dial-up telephone lines (Bell 202C compatible).
- g. Twelve Bell DAAs.
- h. Twelve telephone lines for access to the Facility, arranged in two six line hunt groups: one group for 1200 bps operation and one for 300 bps operation.
- i. An Arpanet "VDH" interface.

4.1.3 Software Acquisition

Phase I also saw the acquisition of all software needed to begin the Phase II operation of the CM/DDF. Software items obtained for the Facility were:

A. Operating system

Although the original proposal suggested the use of the RSX11-D operating systems as the primary system under which the CM/DDF was to run, subsequent evaluation resulted in the selection of the UNIX operating system for this role. UNIX, in contrast to RSX11-D, was designed to support interactive development and execution of programs, making it an ideal match to the development role of the CM/DDF. Various other attributes of UNIX contributed to this success of the CM/DDF:

The use of a high level language --C-- for the operating system and support software allowed the development of specialized software at much lower cost than in the traditional assembler language environment. Specific examples included the changes to support 1200 baud half duplex connections, and support of the Univac 1652 terminal.

The hierarchical file system, which eased the management of the disk space.

The large number of utility programs, which reduced the need to develop new programs.

B. Language processors

- a. PDP11 Assembler.
- b. FORTRAN 4 Plus - an enhanced superset of ANSI standard FORTRAN 4.
- c. C - a general purpose language with approximately the same expressive power as PASCAL, but better suited to system programming efforts.
- d. a dialect of BASIC.

C. Graphics software

- a. PLOT-10 Terminal Control System (runs on the PDP-11/70).
- b. PLOT-10 Advanced Graphics II (runs on the PDP-11/70).

c. PLOT-50 Graph Plot (runs on the Tektronix 4051).

d. Plot-50 Statistics and Mathematics Library
(runs on the Tektronix 4051)

The acquisition of these software items, combined with the hardware acquisition and site preparation activities described above, made possible the Phase II operation of the CM/DDF. In other words, it became possible for Crisis Management contractors to use the Facility for their computation needs as soon as Phase II began.

4.2 Accomplishments of Phase II

By November 1977, CCA began to perform the tasks designated as Phase II operations. The major role of the DDF during this phase was to serve as a computation resource for the Crisis Management Program. Phase II activities of the Facility included:

- operation of the DDF timesharing system.
- user support - to help CMP contractors take full advantage of DDF capabilities.
- packaging of developed programs and data - to

encourage the sharing of data and programs developed by CMP contractors with each other.

- support for demonstration - to permit operational DOD personnel to inspect the Crisis Management aids under development, and to allow them to advise on development directions.

4.2.1 Timesharing System Operation

Providing timesharing computer services to Crisis Management Program contractors was the most basic function of the DDF. The activities which made up this function included:

- operating the system according to schedule.
- isolating and correcting hardware and software errors.
- performing preventive maintenance on hardware.
- backing up stored data and programs on a daily and monthly basis.
- providing recovery services when needed.

System operation also provided services substantially beyond those traditionally provided in such a facility, including:

Counseling on system design for CMP contractors to take

encourage the sharing of data and programs developed by CMP contractors with each other.

- support for demonstration - to permit operational DOD personnel to inspect the Crisis Management aids under development, and to allow them to advise on development directions.

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- performing preventive maintenance on hardware.
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- providing recovery services when needed.

System operation also provided services substantially beyond those traditionally provided in such a facility, including:

Counseling on system design for CMP contractors to take

advantage of unusual system features; ensuring some degree of compatibility among various projects.

Both formal and informal training in effective use of UNIX facilities.

Revision of completed programs to improve their demonstrability.

4.2.2 Software and Database Development

The packaging of software and databases developed at the DDF comprised another area in which the Facility supported Crisis Management R&D. After testing and documentation, CCA managed the internally developed CMP software and databases in the same manner as it managed software obtained from outside sources: CCA advised users through documentation, seminars, and individual consultation. Also, CCA undertook to maintain each software item in cooperation with the CMP contractor who implemented it.

4.2.3 Demonstration

As a final Phase II function, the DDF permitted integrated demonstration of Crisis Management products to operational DOD personnel. These demonstrations served to provide feedback and guidance by operational personnel helping to direct CMP efforts along practical lines. The demonstrations also afforded an effective mechanism for transferring Crisis Management products into operational service.

Overall, the DDF facilitated the demonstration of CMP accomplishments by providing a central location specially structured to contain all of the equipment needed to present each product. In addition, the software "packaging" activity referred to above allowed the products of various contractors to be integrated into a single environment for convenient demonstration.

The activities of Phase II of the DDF proved successful. The demonstration activities, in particular, aroused great interest among DOD personnel in obtaining and using CMP software products. The demand for transfer of the products from the DDF to operating elements grew steadily.

When the Facility became operational in November 1977, it ran twenty-four hours a day, seven days a week. Shortly thereafter, software from two CMP contractors, the Early

Warning and Monitoring System (EWAMS) from Decision and Design, Inc., and the Executive Aid program from CACI, Inc., were transferred to the Facility.

Demonstrations followed in January 1978, addressed to all levels in the program. Key persons who reviewed the initial results included Dr. Robert R. Fossum of ARPA, Dr. David Chevonja of ARPA, Europe, and Carl H. Norton, Deputy Director for Resources & Support/Comptroller. Because of the positive response, high-level members of the intelligence community received introductions to the Facility. Many people from the Defense Intelligence Agency/National Military Intelligence Center (DIA/NMIC), as well as representatives from the Central Intelligence Agency (CIA), attended demonstrations. All who saw the products demonstrated in the DDF responded in an enthusiastic and positive manner.

Demonstrations for DIA resulted in cooperation between ARPA, DIA, and the CIA aimed at making CMP products available to operational elements. For example, the DIA/National Military Intelligence Center (NMIC) loaned the Facility a Univac 1652 dual screen terminal so that the DDF staff could begin work toward incorporating this terminal into the system. In addition, the NMIC devoted a PDP-11/45 computer to receiving and running CMP programs.

4.3 Accomplishments of Phase III

Phase III, which commenced in 1978, saw the completion of system software acquisition and the development of several application software packages. The present section examines these accomplishments.

4.3.1 System Software Acquisition

A full complement of system software to support the DDF was either acquired externally or created internally. These software tools included an operating system, language processors, graphics routines, and a database management system.

The CM/DDF adopted the UNIX operating system developed at Bell Laboratories by Ken Thompson and Dennis Ritchie. As indicated above, UNIX is a multi-purpose, multi-programming, timesharing operating system designed for simplicity and ease of use. Its major features include:

A hierarchical file system.

Simplified I/O structure.

Ability to run background processes.

A flexible system command language.

CM/DDF language processors included the UNIX system's language, called C, and Fortran IV Plus (F4P). Fortran IV Plus is a DEC product modified by Commercial Union Leasing Corporation to run on UNIX. The system includes the compiler, libraries, linker librarian, and a program to convert UNIX object modules for use with F4P. Several features were added by CULC to the standard DEC product, including 512-character buffered I/O, direct access to UNIX system calls, and a preprocessor that allows INCLUDES and DEFINES.

For graphics, the CM/DDF used Tektronix Plot 10 and Plot 50 software. The Plot 10 software included the Terminal Control System (TCS) and Advanced Graphing - II (AG-II) for the Tektronix 4010 family of graphic display terminals. TCS is a set of Fortran IV subroutines residing on the host system that allows graphic programming and provides the foundation for more sophisticated systems, such as AG-II. AG-II works with TCS to provide a wider range of graphical features, such as the ability to specify proportions, shape, and makeup of graphs.

Plot 50 is the Tektronix 4051-based software which provides a very flexible local graphic display system. The entire Plot 50 statistics Program Library was available on-site for stand-alone 4051 statistical analysis. Because the Plot 10 package delivered by Tektronix was not designed to run under the UNIX operating system, the DDF staff successfully completed its conversion to this environment.

Other system software installed in the DDF during Phase III included:

- BMD-P series of statistical programs.
- NED, a powerful text editor.
- RITA, a production rule system which facilitates the creation of easy-to-use human interfaces.

4.3.2 Application Software Development

A series of crisis management related programs were converted to run under UNIX and installed in the DDF. These included:

- A. The Early Warning and Monitoring System (EWAMS) [ANDRIOLE], [WITTMAYER] - an interactive utility that allows the user to track international political indicators on a global, regional, country-pair,

and single country basis. EWAMS uses sophisticated statistical analysis techniques to detect political indicators of a growing international crisis. The raw data on which EWAMS operates are encoded summaries of wire service news stories. The actual encoding was performed by political scientists at the Naval Post-Graduate School in Monterey, California. The summaries were input to the DDF in real time over leased communication lines. Thus, EWAMS had an up-to-date database on which to operate.

Users were asked to choose a region, country-pair, or single country to be analyzed. The program computed and displayed indicators of international activity and tension based on information extracted from news stories. For example, if the user chose to examine the interactions of Israel and Egypt between February 1977 and January 1978, the program displayed an analytical graph on the large screen at the CM/DDF. The results indicated strongly increasing activity (a potential crisis) toward the end of the period. The potential crisis might be further analyzed by employing additional statistical capabilities of EWAMS. In addition, the user could examine textual summaries of the actual events. Information was grouped so that the user could select

cooperative events, conflicting events, both, or some other selective category. Quantitative indicators for crisis management included foreign, domestic, and international political, military, and economic attributes. Tests of this system showed that EWAMS can provide important indicators of impending crises.

B. The Executive Aid for Crisis Management [CACI] was developed to provide ready access to the historical record of recent U.S. crisis operations for DOD personnel and to prescribe actions in real-time. The user searched the Executive Aid database for historical precedents and analogies in the course of considering crisis options. The complete database contained information of 307 U.S. crises for the period 1946-1976. Three subsets from the database were constructed for use with the Executive Aid (yielding three distinct executive aids):

- a. A file of 101 crisis operations which could be examined with the focus on U.S. actions and objectives.
- b. A file of 41 crises from the period 1956-1976, which could be accessed with emphasis on describing and forecasting the crisis

management problems.

- c. The complete set of 307 crises, which could be searched for descriptive information concerning U.S. military management during each incident, along with a set of general crisis descriptors.

The user employed the Executive Aid to obtain background information about crises in recent history. For example, the user might choose to identify crises with particular U.S. objectives. The objectives chosen might be preserve, restore, or improve alliance. The Executive Aid then selected those crises in its database in which these U.S. objectives were present. The results appeared in list form on the screen. The visitor could then ask for additional information about, or summary descriptions of, each of these crises, such as the U.S. actions taken in cases where it had an interest.

- C. The Ultra Rapid Reader (URR) - a demonstrational piece of software intended to show how quickly reading can be accomplished without significant eye movement. The URR presents text in the center of a Tektronix 4025 terminal screen, one (two if hyphenated) word at a time. This is done at different rates of speed to determine how quickly read-

ing proceeds. The sample text used in this system came from news stories in the Washington Post.

D. Data routines for on-line entry of World Event Interaction Survey (WEIS) [McCLELLAND et al] were installed at the CM/DDF. WEIS data formed the basis of EWAMS computations.

E. The Multi-Attribute Utility (MAU) system is an example of the technique of hierarchical decomposition of complex decisions. The system supports single level, multi-attribute utility analysis which provides the user with the ability to evaluate separate criteria using a thermometer setting technique. The system includes the automatic generation of a utility curve based on user inputs.

5. Conclusion

The Crisis Management Program was effectively supported by the DDF following its creation in 1977. Considered from an experimental viewpoint, the CM/DDF was used to test the concept of a DDF. CCA later continued its support of CMP research by integrating it into the more comprehensive CTO/DDF.

In addition, the utility of the DDF concept in facilitating technology transfer of research products to operational environments was effectively demonstrated.

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