DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150537

SITE SELECTION FOR MSFC OPERATIONAL TESTS OF SOLAR HEATING AND COOLING SYSTEMS

Prepared by

IBM Corporation
Federal Systems Division
Huntsville, Alabama 35805

Under Contract NAS8-32036 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

for the U. S. Department of Energy

(NASA-CR-150537) SITE SELECTION FOR MSFC OPERATIONAL TESTS OF SOLAR HEATING AND COOLING SYSTEMS (IBM Federal Systems Div.) 49 p HC A03/MF A01 CSCL 10A

N78-19602

Unclas
G3/44 07291

U.S. Department of Energy

Solar Energy

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. DOE/NASA CR-150537	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Site Selection for MSFC Operational Tests of Solar Heating and Cooling Systems		5. REPORT DATE February 10, 1978
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT # IBM 78W-00009
9. PERFORMING ORGANIZATION NAME AND ADDRESS IBM Corporation Federal Systems Division Huntsville, Alabama 35805		10. WORK UNIT NO.
		11. CONTRACT OR GRANT NO. NAS8-32036
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		13. TYPE OF REPORT & PERIOD COVERED Contractor Report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This work was accomplished under the technical management of Earle G. Harris, Marshall Space Flight Center, Alabama.

16. ABSTRACT

Site selection guidelines for the sixty Marshall Space Flight Center operational test sites are presented. Included are site selection criteria, methodology, and sequence.

17. KEY WORDS	18. DISTRIBUTION STATEMENT Unclassified-Unlimited William A. Brooksbank, Jr. WILLIAM A. BROOKSBANK, JR. Manager, Solar Heating & Cooling Project Ofc

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	47	NTIS

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

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INTRODUCTION

In response to MSFC Technical Directive No. 8 under the SIMS program, IBM has studied the criteria, methodology and sequence aspects of the site selection process for the 60 MSFC operational test sites. Each of these three aspects is covered in separate sections of this report.

The information presented should be treated as guidelines, not as rigorous requirements, since site selection procedures are subject to many subtle conditions which are weighted by the particulars of each proposed Operational Test Site. This report does organize the logical thought process that should be applied to the site selection process, but final decisions are likely to be highly subjective.

SITE SELECTION CRITERIA

A listing of site selection criteria is presented in this section considering hot water, space heating/hot water and space heating/cooling/hot water system applications. Criteria is defined in two levels or categories: (1) unique criteria associated with the operational test sites, and (2) a generalized check list.

LEVEL 1 - OPERATIONAL TEST SITE PREEMPTIVE CRITERIA

- Locally available and accredited proctorship
- Varying economic and climatic conditions
- Communications for data transmission to central processing site
- Technical awareness of owner/occupant
- Ease of access for development team
- Accessibility for testing and evaluation by development team
- Ease of removal/replacement of components
- Availability of subcontractors for installation and maintenance
- Freedom from failure restraints
- Accommodate complete shutdown of solar energy system, replacement of system or subsystem
- Climatic conditions representative of desired zone
- Economic conditions representative of desired zone
- Solar system installation compatibility

Additional Pre-emptive Criteria for First Installation of a System Type or Technology

- Isolation from external interference
- Immediate availability of acceptable facility
- Freedom from legal delaying factors
- No more than one day round trip travel time by car required by the development team.
- A high degree of cooperative, technical proctorship
- Not in mainstream of public flow

LEVEL 2 - COMMUNITY/SITE EVALUATION CHECKLIST

- o AREA SURVEY
  - Location
  - Population Trends
  - Income Trends
  - Consumer Characteristics
- o SOLAR ECONOMICS
- o ENERGY CONSERVATION
- o BASIC MATERIALS AND SERVICES
  - Raw Materials
  - Semi-Finished Materials
  - Storage Facilities
  - Routine Supplies
  - General Services
  - Technical Services
- o LABOR
  - Labor Force Inventory
  - Wages and Hours
  - Productivity
  - Industrial Relations
  - Vocational Training
  - Labor Legislation
- o TRANSPORTATION
  - Location Economics
  - Rail Transportation
  - Highway Transportation
  - Trucking Service
  - Other Motor Transportation
  - Commercial Air Service
- o POWER AND FUEL
  - Power Source
  - Electric Power Supply
  - Gas Service
  - Coal, Oil

- LIVING CONDITIONS
    - Attitude and Reputation of Community
    - Building/Living/Utility Costs and Taxes
    - Air Pollution Indices
    - Security from Vandalism, Theft and Disruptive Situations
    - General Usage of Energy Types and Application

- ACCESSIBILITY
    - Ease of Access Transportation
    - Quality of Access
    - Quality of Accommodations
    - Quality of Communications

- ENVIRONMENT
    - Zoning: Practicality and Workability of Code
    - Quality and Type of Local Government
    - Adequacy of Public Services: Police, Fire, Etc.
    - Local Issues
    - Attitude Toward Innovative Architecture

- ECONOMICS
    - Construction Cost Index Comparisons
    - Availability of Skills
    - Availability of Service Industries
    - I/R Problems

- PUBLIC RELATIONS
    - Community Desire to Welcome Test Facility
    - Community Ability to Understand Purpose
    - Freedom from Special Problems that Would Create unfavorable Climate
    - Likelihood of Favorable Atmosphere to Continue

- EDUCATION
  - Special Facilities
  - Trade and Business Courses
  - Colleges and Universities in 50-Mile Radius
  - Vocational Schools, Courses Offered, Curricula Flexibility

- POLICE AND FIRE PROTECTION
  - Law Enforcement
  - Civil Defense
  - Fire Protection

- PLANNING AND ZONING
  - Planning Commission
  - Zoning
  - Building Codes
  - Traffic and Parking
  - Streets

- LOCAL GOVERNMENT AND TAXES
  - Structure of Municipal Government Elected and Appointed Officials
  - Financial Condition
  - Civic Attitudes
  - Local Taxes

- STATE GOVERNMENT AND TAXES
  - State Regulations and Legislation
  - State Taxes
  - Total State and Local Tax Load
  - Future Tax Prospects in the Area

- FEDERAL ACTIVITIES IN AREA
  - Nearby Government Installations, Federal Aid to Schools in Impacted Areas
  - Incentives Offered in Depressed Areas - Special Consideration Offered in Contract Awards in Depressed Areas

- TELECOMMUNICATIONS
  - Accommodate Data Return to Central Site
- CLIMATE
  - Monthly Average Maximum and Minimum and Long-time Extreme Temperatures
  - Degree Days by Month
  - Number of Days Over 90^o and Number Under 32^o
  - Period Between Killing Frosts
  - Average Monthly Rainfall, Snowfall
  - Maximum Rainfall, Snowfall in 24 Hours
  - Monthly Averages of Relative Humidity
  - Monthly Wind Velocity, Prevailing Wind Direction
  - Number of Clear, Partly Cloudy and Cloudly Days
  - Number of Days with Poor Visibility and Low Ceilings
  - Special Weather Hazards
  - Climatic Effects
- REPRESENTATION IN CONGRESS
  - Voting Record of Representatives and Senators
  - Committee Position Held by Area Representatives
- FINANCING
  - Requirements
  - Source of Funds
  - Credit Factors
  - Factors Effecting Loan Terms
  - Special Inducements
- INDIVIDUAL SITES
  - Solar Adaptability
  - Requirements
  - Type of Site
  - Geologic Considerations
  - Accessibility - see Transportation
  - Utilities - See Power and Fuel, Water and Waste Disposal
  - Cost of Extending Utilities
  - Intangible Considerations
  - Legal Check-Points
  - Cost of Land

- SIZE AND CAPABILITY
  - Planned Configuration and Height
  - Planned Size (Sq. Ft. of Occupied Space)
  - Planned Test Capability
  - Planned Energy Requirement
  - Possible Variations

- LAND REQUIREMENTS
  - Topography Desired
  - Maximum Obstruction Heights (Location & Distance)
  - Set Back Requirement
  - Size and Ratio of Buildable to Total
  - Special Considerations (Local Phenomena)

- UTILITY AND SPACE REQUIREMENTS
  - Water
  - Power

- SPECIAL ENVIRONMENTAL RESTRICTIONS
  - Immediate Local Area
  - Community
  - Accessible Region
  - Possible Variation

SITE RANKING METHODOLOGY

A methodology has been generated for ranking alternative sites. Based upon Operational Test Site objectives and criteria, an alternative site evaluation procedure is presented along with a typical installation.

The material in this section is prepared in outline format in order to highlight only the important aspects of this portion of the site/criteria study, and to be directly applicable to oral presentations.

An applicable decision analysis technique, the Kepner-Tregoe Method, is outlined in this section. A detailed explanation of this method is contained in the Appendix of this report.

OPERATIONAL TEST SITE OBJECTIVES

- VERIFY PERFORMANCE SPECIFICATIONS
- VERIFY INTERIM PERFORMANCE CRITERIA
- VERIFY INSTALLATION/OPERATION/MAINTENANCE INSTRUCTIONS
- ESTABLISH LOCAL TRADE CAPABILITY
- PROVIDE OPERATIONAL DATA BASE
- PROVIDE FOR TESTING IMPROVEMENTS
- DETERMINE LIFE CYCLE DATA
- IDENTIFY COMMUNITY AND TECHNICAL PROBLEMS
- VERIFY LONG TERM PERFORMANCE PREDICTION OVER A WIDE RANGE OF CLIMATIC AND ECONOMIC CONDITIONS
- TECHNOLOGY AND SYSTEM DEVELOPMENT ADVANCEMENT THRU HIGH RISK TESTING
- SYSTEM APPLICATION AND SITE SELECTION IN AREAS OF GREATEST MARKET APPLICABILITY

UNIQUE NASA ROLE IN SOLAR PROGRAM

- ESTABLISH EMPIRICAL DATA BASE IN EVERY UNIQUE CLIMATIC ZONE IN THE U.S.
- ESTABLISH THE OPTIMUM SYSTEMS INSTALLATIONS IN EACH ZONE, UTILIZING MARKETABLE SUB-SYSTEMS
- ESTABLISH BASIS FOR SIMPLIFIED DESIGN HANDBOOKS FOR LOCAL DESIGN EFFORT IN EACH CLIMATIC ZONE
- DEVELOPMENT TESTING
- TECHNOLOGY AND SYSTEM DEVELOPMENT ADVANCEMENT

OPERATIONAL TEST SITE CRITERIA

- LOCALLY AVAILABLE AND ACCREDITED TECHNICAL OVERVIEWER
- VARYING ECONOMIC AND CLIMATIC CONDITIONS
- COMMUNICATIONS FOR DATA TRANSMISSION TO CENTRAL PROCESSING SITE
- TECHNICAL AWARENESS OF OWNER/OCCUPANT
- FLEXIBILITY OF CODES FOR DEVELOPMENT ENVIRONMENT
- EASE OF ACCESS FOR DEVELOPMENT TEAM
- ACCESSIBILITY FOR TESTING AND EVALUATION BY DEVELOPMENT TEAM
- EASE OF REMOVAL/REPLACEMENT OF COMPONENTS
- AVAILABILITY OF SUBCONTRACTORS FOR INSTALLATION AND MAINTENANCE
- FREEDOM FROM FAILURE RESTRAINTS
- ACCOMMODATE COMPLETE SHUTDOWN OF SOLAR ENERGY SYSTEM, REPLACEMENT OF SYSTEM OR SUBSYSTEM

OPERATIONAL TEST SITE CRITERIA (CONTINUED)

- CLIMATIC CONDITIONS REPRESENTATIVE OF DESIRED ZONE
- ECONOMIC CONDITIONS REPRESENTATIVE OF DESIRED ZONE
- SOLAR SYSTEM INSTALLATION COMPATIBILITY
- INSTALLATION OF FIRST SYSTEM TYPE WITHIN APPROXIMATELY 100 MILES OF MSFC

CRITERIA COMPLIANCE TYPICAL INSTALLATION BY BUILDING CATEGORIES

PRE-EMPTIVE CRITERIA	PRIVATE	UNIVERSITY	GSA	DOD
ACCREDITED TECHNICAL OVERVIEWER	o	✓	o	o
VARYING CONDITIONS	✓	✓	✓	✓
COMMUNICATIONS	✓	✓	✓	✓
TECHNICAL AWARENESS	✓	✓	✓	✓
CODE FLEXIBILITY	o	✓	o	o
ACCESS	o	✓	✓	✓
REMOVAL/REPLACEMENT	o	✓	o	✓
SUB-CONTRACTORS	✓	✓	✓	o DAVIS-BACON ACT
NO FAILURE RESTRAINTS	o	✓	o	✓
ACCOMMODATE SHUTDOWNS	o	✓	o	✓
REPRESENTATIVE CLIMATE	✓	✓	✓	✓
REPRESENTATIVE ECONOMICS	✓	✓	✓	✓
SOLAR COMPATIBILITY	✓	✓	✓	✓

ALTERNATIVE SITE EVALUATION

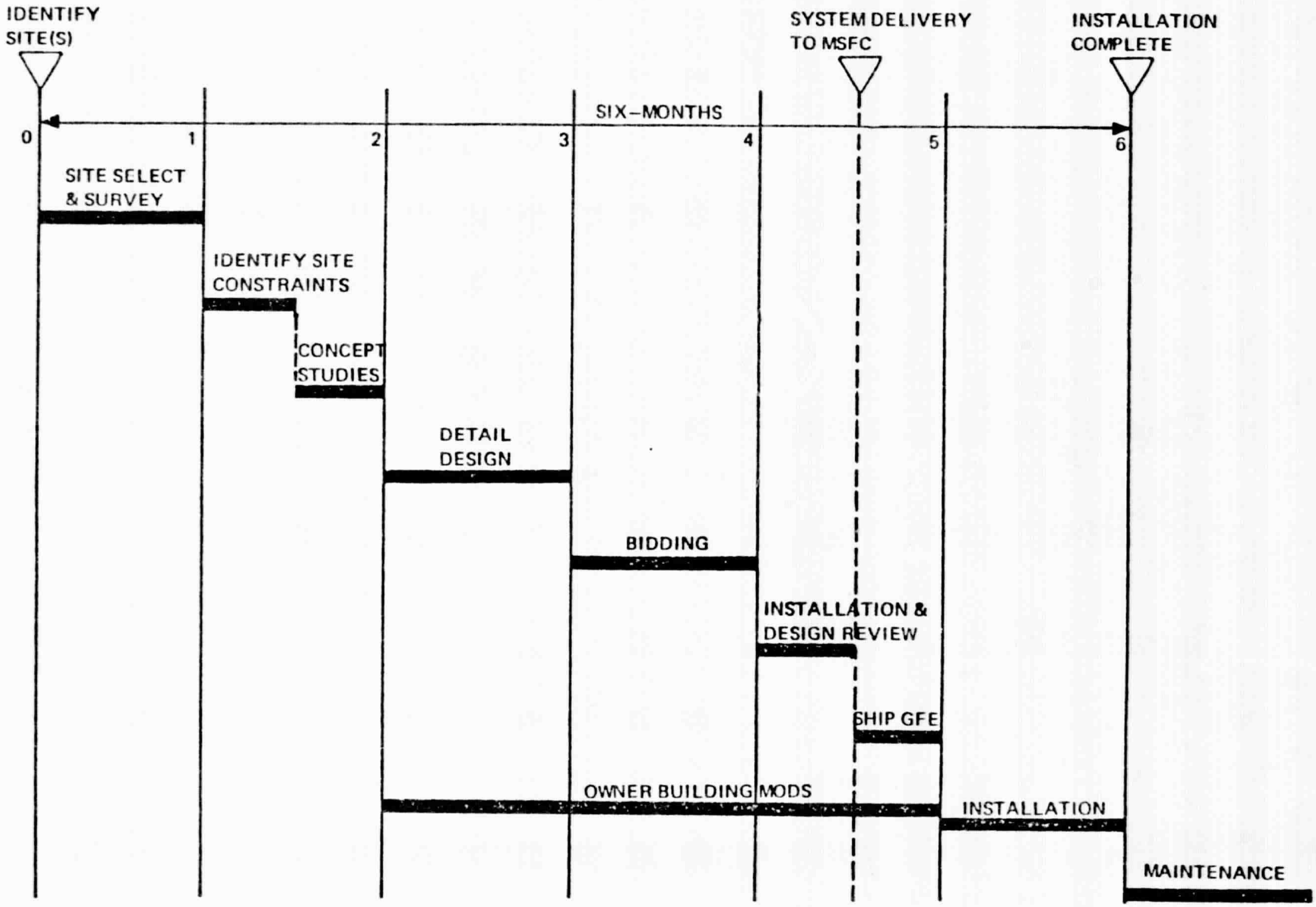
- THREE PHASE ALTERNATIVE REDUCTION METHOD
  - CRITERIA EVALUATION
  - COMMUNITY SELECTION CHECKLIST
  - TECHNICAL CHECKLIST
- CRITERIA EVALUATION
  - SITES RANKED BY BASIC CRITERIA
- COMMUNITY SELECTION
  - SURVIVING CANDIDATE SITES RANKED BY COMPOSITE COMMUNITY OBJECTIVES SCORE
  - KEPNER-TREGOE PROCESS
- TECHNICAL SELECTION
  - SURVIVING CANDIDATE SITES RANKED BY COMPOSITE TECHNICAL OBJECTIVES SCORE
  - KEPNER-TREGOE PROCESS
  - SELECT SITE WITH BEST COMBINATION OF OBJECTIVE SCORE AND ADVERSE CONSEQUENCE SCORE

KEPNER-TREGOE PROCESS

- SET OBJECTIVES (TECHNICAL OR COMMUNITY)
- WEIGHT OBJECTIVES (ASSIGN RELATIVE IMPORTANCE)
- SELECT ALTERNATIVES
  - COMMUNITY DECISION INPUT: ALL SITES SURVIVING PRE-EMPTIVE SELECTION
  - TECHNICAL DECISION INPUT: SITES RANKED HIGHEST IN COMMUNITY DECISION PROCESS
- EVALUATE ALTERNATIVES AGAINST OBJECTIVES
  - "HOW WELL DOES ALTERNATIVE A MEET OBJECTIVE 1"
- CHOOSE THE BEST ALTERNATIVE AS A TENTATIVE SOLUTION
- ASSESS ADVERSE CONSEQUENCES OF TENTATIVE SOLUTION
- CONTROL THE EFFECTS OF FINAL SOLUTION
  - JUDGEMENT OF HIGHEST OBJECTIVE SCORE VS. LOWEST ADVERSE SCORE

SITE SELECTION SCHEDULES

TYPICAL INSTALLATION – ELAPSED TIME SEQUENCE



CONCLUSIONS/RECOMMENDED APPROACH

- ALL SITES SATISFYING CRITERIA ARE ACCEPTABLE FOR CONSIDERATION
- UNIVERSITIES AND DOD SITES MOST PROMISING
- SELECT HUNTSVILLE AS FIRST SITE - IMMEDIATE ACTION TO INVESTIGATE REDSTONE AND UAH SITE POSSIBILITIES
- JOINT ERDA/MSFC EFFORT TO SELECT REMAINDER OF SITES - EXAMINE UNIVERSITIES, DOD AND GSA CANDIDATES
- DETERMINE CANDIDATE SITES IN DESIRED ZONES. ZONES TO BE DEFINED BY MSFC.
    - VARYING CLIMATIC CONDITIONS
    - GREATEST MARKET CAPTURE
- DEFINE SEQUENCE OF SYSTEM TYPE INSTALLATION
    - IN ORDER OF GREATEST POPULATION
- DETERMINE SITE ACQUISITION METHOD(S) AFTER CANDIDATES DETERMINED

ZONE AND APPLICATION SEQUENCE

This section consists of two major areas: (1) definition of regions with common environmental characteristics, and (2) assignment of solar energy system application by region and a preferred listing of the sequence of installation based upon population capture.

REGIONALIZATION

Heating regions are defined on the basis of the need for solar augmentation of a conventional system and the availability of solar energy to implement that augmentation. The economic consideration of the cost of the energy being displaced by the solar system is a long term factor, but is not used in this report to establish zones of common environmental conditions.

NEED FOR SOLAR AUGMENTATION

The need for solar augmentation of conventional heating systems is principally determined by the heating load which must be supplied by the system. This is a function of outside air temperature, and the number of days in the heating season during which the inside air temperature must be raised to comfortable living temperatures. The National Oceanic and Atmospheric Administration of the U.S. Department of Commerce maintains weather stations thoughout the continental United States, Alaska, Hawaii and possessions of the United States which measure and accumulate climatological data. Each year a pamphlet, "Local Climatological Data-Annual Summary with Comparative Data," is prepared for each of some 286 weather stations. One parameter included in that pamphlet is the average heating season degree-days. The heating season degree-day requirements vary from a few hundred degree-days in the southern United States to greater than 10,000 degree-days in the North Central United States.

The need for solar augmentation increases as the degree-day heating load increases; therefore, it is convenient to characterize regions of the United

States in accordance with the heating degree-day load the region experiences. For purposes of regionalization, 1,000 degree-day increments were chosen as the granularity of categorization.

Table I presents the code, degree-day range and a typical city falling within that range which is utilized for characterization of regions in accordance with their need for solar augmentation.

AVAILABILITY OF SOLAR ENERGY

A second significant parameter of characterization is the availability of solar energy to provide solar augmentation of conventional systems. In many regions of the United States, typically, a high number of degree-day requirements is accompanied by a low availability of solar energy due to cloud cover, storm frequency, etc. The mean daily solar radiation available in a geographical area during the heating season is typified by the mean daily solar radiation for the month of January, which is published in the NOAA document "Climates of the United States."

During the heating season, the mean daily solar radiation measured in Langleys falling on the United States ranges from less than 100 Langleys in the Pacific Northwest to 350 Langleys in the South and Southwest. It is convenient to subdivide the range between zero and 350 Langleys into 6 categories.

Table II presents the categorization code, mean daily solar radiation, and a typical city having mean daily solar radiation at the indicated level.

Table I. Solar Augmentation Need Categorization Criteria

CODE	DEGREE-DAY RANGE	TYPICAL CITY
1	< 1000	Miami
2	1000 - 2000	Los Angeles
3	2000 - 3000	San Francisco
4	3000 - 4000	Atlanta
5	4000 - 5000	Washington
6	5000 - 6000	Boston
7	6000 - 7000	Detroit
8	7000 - 8000	Milwaukee
9	8000 - 9000	Minneapolis
10	> 9000	Duluth

Table II. Solar Energy Availability Categorization Criteria

CODE	INSOLATION RANGE	TYPICAL CITY
1	< 100	Seattle
2	100 - 150	Detroit
3	150 - 200	Washington
4	200 - 250	Atlanta
5	250 - 300	Los Angeles
6	300 - 350	Miami

STANDARD METROPOLITAN STATISTICAL AREAS

The Office of Management and Budget periodically divides the country into "Standard Metropolitan Statistical Areas." There are currently 266 SMSAs defined. An SMSA typically defines a group of counties surrounding a centrally located city, the name of which is attached to the SMSA. Approximately 75 percent of the population resides in the set of 266 SMSAs.

From the standpoint of market exposure, it is significant to locate solar energy systems in places where the resulting data has the widest applicability. Thus, consideration is given to locating sites in the regions (groups of SMSAs) which expose a maximum population group to solar energy systems applications.

In Table III, 258 of the 266 SMSAs were distributed among 21 groups having similar insolation and degree-day heating requirements. It will be noted that the SMSAs are not necessarily contiguous. We can take advantage of this by selecting sites in the 21 groups which minimize travel time, expense, etc. without compromising the goal of covering all 21 zones. The eight SMSAs not included have small populations and are located in unique zones. It was not deemed necessary to include them, and their exclusion has no impact on site selection.

It has been suggested that a university environment provides the best background for the operational test site proof-of-performance demonstration. Using this criterian, and also specifying that the university must have an accredited Engineering Department, provides the rationale for selecting specific geographic locations for calculation purposes. The climatic conditions of the university cities were used to calculate the performance indices ($1kw-hr solar) appearing in tables IV, V and VI. The university and location are typical of the zone and should not be interpreted as final site selections.

Table III. SMSA Groups

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
43	University of Alabama, Huntsville	Huntsville, AL	Huntsville	AL
			Florence	
			Memphis	TN
			Nashville	
			Knoxville	
			Chattanooga	
			Clarksville	
			Little Rock	AR
			Pine Bluff	
			Greensboro	NC
			Charlotte	
			Burlington	
			Greenville	SC
44	Georgia Tech	Atlanta, GA	Ft. Smith	AR
			Fayetteville	
			Atlanta	GA
			Oklahoma City	OK
			Tulsa	
			Norfolk	VA
			Richmond	
			Newport News	
			Petersburg	
			Raleigh	NC
52	VPI	Blacksburg, VA	Kingsport	TN
			Richland	WA
			Asheville	NC
			Springfield	MO
			Roanoke	VA
			Lynchburg	
			Huntington	WV
			Charleston	
			Parkersburg	
			Cincinnati	OH
			Hamilton	

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
53	University of Louisville	Louisville, KY	Washington Evansville Baltimore St. Louis Vineland Nassau-Suffolk Poughkeepsie Wilmington New Brunswick Trenton Atlantic City Philadelphia New York City Louisville Lexington Owensboro	DC IN MD MO NJ NY DE NJ PA NY KY
62	Ohio State University	Columbus, OH	Canton Dayton Lima Steubenville Williamsport Wheeling Columbus Mansfield Springfield Pittsburgh Johnstown Altoona	OH PA WV OH PA
102	University of Minnesota	Duluth, MN	Duluth	MN
16	University of Miami	Miami, FL	Miami Tampa Ft. Lauderdale Orlando W. Palm Beach Sarasota Ft. Meyers Melbourne	FL

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
15	Texas A&I University	Kingsville, TX	Corpus Christi	TX
			McAllen	
			Brownsville	
83	University of Wisconsin	Madison, WI	Billings	MT
			N. E. Pennsylvania	PA
			Madison	WI
			LaCrosse	
			Rochester	MN
			Dubuque	IA
			Cedar Rapids	
			Waterloo	
			Portland	ME
			Lewiston	
			Manchester	NH
			Nashua	
			Binghamton	NY
			Elmira	
			Sioux Falls	SD
93	North Dakota State University	Fargo, ND	Minneapolis	MN
			St. Cloud	
			Fargo	

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
63	Purdue University	Lafayette, IN	Boise City	ID
			Springfield	IL
			Anderson	IN
			Muncie	
			Provo	UT
			Omaha	NE
			Lincoln	
			Boston	MA
			Lawrence	
			Lowell	
			Fall River	
			Newark	NJ
			Jersey City	
			Patterson	
			York	PA
			Reading	
			Providence	RI
			New Bedford	MA
			New Haven	CT
			Bridgeport	
			Stanford	
			Norwalk	
			New London	
			Champaign	IL
			Decatur	
			Brockton	MA
			Kansas City	MO
			St. Joseph	
			Columbia	
			Longbranch	NJ
			Topeka	KS
			Indianapolis	IN
			Terre Haute	
			Lafayette	
			Allentown	PA
			Harrisburg	
			Lancaster	
			Salt Lake City	UT

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
64	University of Denver	Denver, CO	Denver Pueblo	CO
72	Notre Dame University	South Bend, IN	Spokane Yakima Ft. Wayne South Bend Lansing Gary Springfield Pittfield Detroit Grand Rapids Kalamazoo Ann Arbor Battle Creek Muskegon Jackson Cleveland Toledo Akron Youngstown Lorain Chicago Worcester Erie Fitchburg	WA IN MI IN MA MI OH IL MA PA MA

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
73	Bradley University	Peoria, IL	Hartford	CT
			Peoria	IL
			Bloomington	
			Des Moines	IA
			Buffalo	NY
			Rochester	
			Albany	
			Syracuse	
			Utica	
			Waterbury	CT
			New Britain	
			Danbury	
			Bristol	
			Meriden	
			Rockford	IL
			Davenport	IA
			Sioux City	
82	Marquette University	Milwaukee, WI	Ray City	MI
			Great Falls	MT
			Appleton	WI
			Flint	MI
			Saginaw	
			Green Bay	WI
			Milwaukee	
			Racine	
			Kenosha	

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
34	University of Alabama, Tuscaloosa	Tuscaloosa, AL	Montgomery	AL
			Birmingham	
			Tuscaloosa	
			Anniston	
			Gadsden	
			Bakersfield	CA
			Augusta	GA
			Columbus	
			Macon	
			Shreveport	LA
			Alexandria	
			Monroe	
			Jackson	MS
			Columbia	SC
			Texarkana	TX
			Tyler	
			Wilmington	NC
24	Louisiana State University	Baton Rouge, LA	Mobile	AL
			Pensacola	FL
			New Orleans	LA
			Baton Rouge	
			Lake Charles	
			Lafayette	
			Biloxi	MS
			Beaumont	TX
			Houston	TX
			Galveston	TX

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
25	University of Florida	Gainesville, FL	Riverside	CA
			Jacksonville	FL
			San Antonio	TX
			Austin	
			Bryan	
			Los Angeles	CA
			Anaheim	
			San Diego	
			Tallahassee	FL
			Gainesville	
			Daytona Beach	
			Savannah	GA
			Laredo	TX
			Phoenix	AZ
			San Angelo	TX
33	Fresno State College	Fresno, CA	San Francisco	CA
			San Jose	
			Fresno	
			Stockton	
			Salinas	
			Vallejo	
			Santa Rosa	
			Santa Cruz	
			Sacramento	CA
			Modesto	
			Fayetteville	NC

Table III. SMSA Groups (Continued)

ZONE	UNIVERSITY	LOCATION	SMSAs COVERED	
35	Southern Methodist University	Dallas, TX	Dallas	TX
			Killeen	
			Waco	
			Wichita Falls	
			Odessa	
			Midland	
			Sherman	
			Lawton	OK
			Charleston	SC
			Oxnard	CA
			Santa Barbara	
			Abilene	TX
			Albany	GA
			Las Vegas	NV
51	University of Washington	Seattle, WA	Portland	OR
			Eugene	
			Salem	
			Seattle	
			Tacoma	WA

Table IV. Hot Water System Selection Sequence

HOT WATER ONLY REGION	DOLLARS/KW-H SOLAR
MIAMI	.1509084
DENVER	.1518388
FRESNO	.1519807
KINGSVILLE	.1552910
BATON ROUGE	.1579772
DALLAS	.1648333
GAINESVILLE	.1676899
TUSCALOOSA	.1709703
ATLANTA	.1719833
HUNTSVILLE	.1833919
LOUISVILLE	.1884082
PEORIA	.1884956
COLUMBUS	.1908413
SOUTH BEND	.1951015
MILWAUKEE	.1962794
LAFAYETTE	.1969929
MADISON	.1998999
BLACKSBURG	.2011366
DULUTH	.2023887
FARGO	.2049919
SEATTLE	.2270371

Table V. Hot Water/Space Heating Selection Sequence

COMBINED HOT WATER AND SPACE HEAT REGION	DOLLARS/KW-H SOLAR
DENVER	.0448322
FRESNO	.0460317
DALLAS	.0511563
BATON ROUGE	.0515690
TUSCALOOSA	.0519777
ATLANTA	.0521984
PEORIA	.0542989
HUNTSVILLE	.0544144
LOUISVILLE	.0549020
COLUMBUS	.0550519
GAINESVILLE	.0553111
SOUTH BEND	.0559787
MILWAUKEE	.0561213
LAFAYETTE	.0567989
MADISON	.0571555
KINGSVILLE	.0571908
DULUTH	.0574130
FARGO	.0581315
BLACKSBURG	.0584639
SEATTLE	.0647814
MIAMI	.1219967

Table VI. Combined System Selection Sequence

COMBINED SYSTEM REGION	DOLLARS/KW-H SOLAR
DENVER	.0825256
MIAMI	.0841667
KINGSVILLE	.0886936
FRESNO	.0906306
BATON ROUGE	.0956214
DALLAS	.0957156
PEORIA	.0959059
COLUMBUS	.0976421
MILWAUKEE	.0979433
TUSCALOOSA	.0982605
SOUTH BEND	.0983273
DULUTH	.0988725
LOUISVILLE	.0990930
GAINESVILLE	.0996851
MADISON	.0996954
ATLANTA	.0999849
FARGO	.1000225
LAFAYETTE	.1005569
HUNTSVILLE	.1012910
BLACKSBURG	.1054316
SEATTLE	.1136792

SITE SELECTION/SYSTEM TABLES

A typical system set was used to establish a preferred order for installation. First, a system was selected to supply hot water at a constant load of 0.305 KW. Insolation values typical of the 21 zones were used to establish the level of available solar energy. Applying a 40 percent efficiency factor and calculating the collector area required to supply 100 percent of the hot water load on a monthly basis, then calculating a rough optimum (RMS) collector area provided a parameter upon which solar costs are estimated. Table IV presents the zone-characteristic city and tabulates, in ascending order, the cost of solar energy in dollars/KW-h. This table provides a direct comparison between zones and to electric utility rates. The first-listed candidate zones are best selections for hot water systems.

Table V was derived by adding a space heating load (as a function of average ambient temperature) to the constant hot water load. The collector area computations were accomplished in the same sequence as for hot water for the winter months (months having average temperatures less than 65°F) and then merged with the hot water collector areas. The RMS collector area was used to establish the composite cost of solar energy/KW-h.

Table VI was derived by merging the composite hot water and space heating collector areas with the collector areas calculated to provide an RMS cooling load based upon equations adapted from Löf and Tybout. Cooling load is a function of both temperature and humidity.

POPULATION EXPOSURE

Figure I presents a curve illustrating the percent of market exposure as a function of climatic zones. The selection of sites should be biased by the degree of market applicability of a system type.

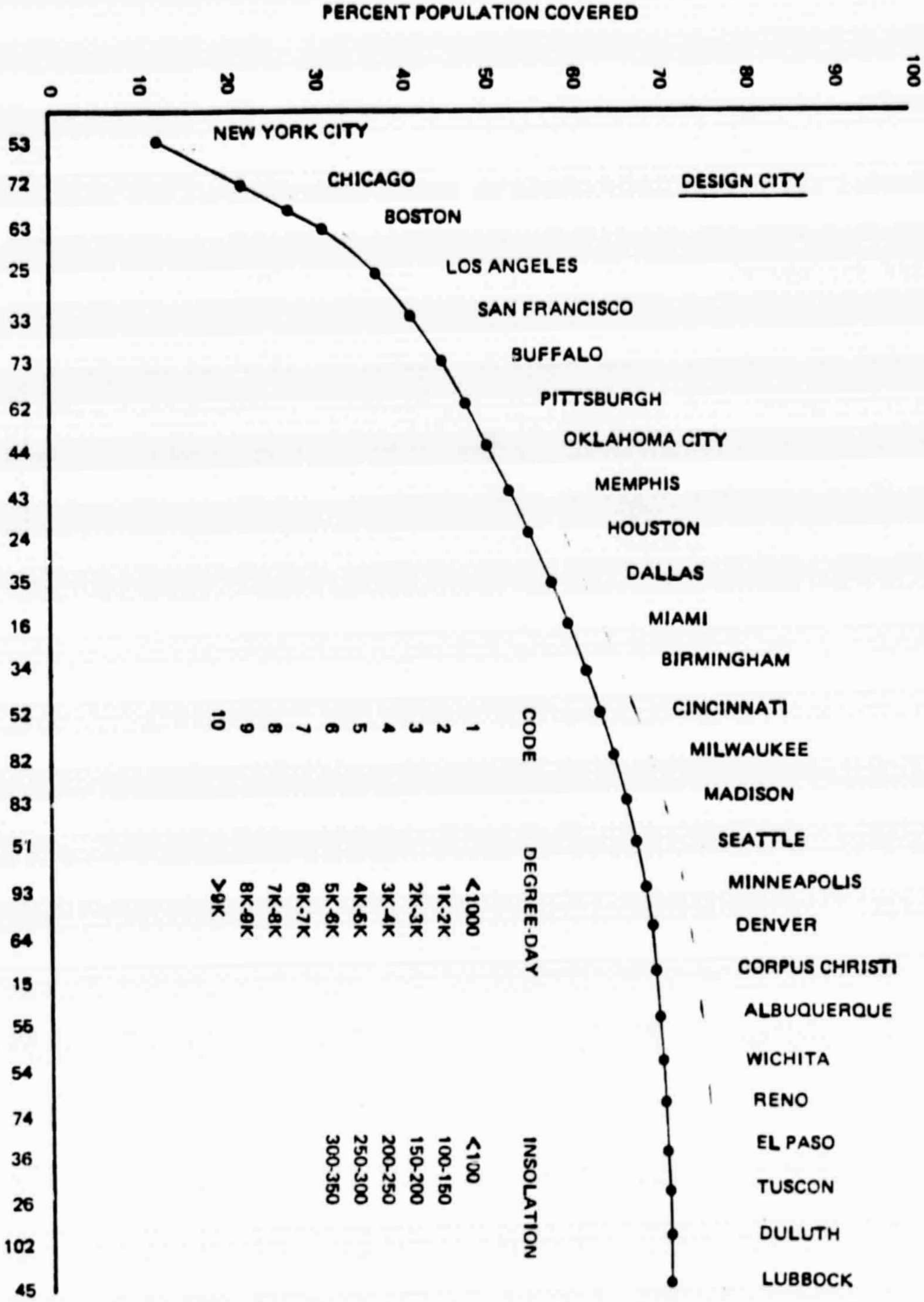


Figure 1. Degree-Day/Insolation Regions vs Percent Population

PREFERRED INSTALLATION SEQUENCE

Table VII presents the preferred installation sequence for residential applications of solar energy systems. The sequence is based first upon maximum market exposure and second upon system economic performance. The first installations of a type are all placed in Huntsville for the convenience of the MSFC and IBM engineers.

Another method of site selection which is equally valid is to ignore the market exposure aspect and proceed with installation in order of economic performance. Such a sequence would follow Table V (except Miami), Table VI, then Table IV in ascending order of cost/KW-h.

Table VII. Preferred Installation Sequence

TYPE	ZONE	LOCATION
HW/SH	43	Huntsville, AL
HW/SH	53	Louisville, KY
HW/SH/C	43	Huntsville, AL
HW/SH/C	72	South Bend, IN
HW/SH	63	Lafayette, IN
HW	43	Huntsville, AL
HW	25	Gainesville, FL
HW/SH	33	Fresno, CA
HW/SH	73	Peoria, IL
HW/SH/C	73	Peoria, IL
HW/SH/C	62	Columbus, OH
HW/SH	44	Atlanta, GA
HW/SH	24	Baton Rouge, LA
HW/SH	35	Dallas, TX
HW	16	Miami, FL
HW/SH	34	Tuscaloosa, AL
HW	52	Blacksburg, VA
HW/SH/C	82	Milwaukee, WI
HW/SH/C	83	Madison, WI
HW/SH	83	Madison, WI
HW/SH	51	Seattle, WA
HW/SH/C	93	Fargo, ND
HW/SH	64	Denver, CO
HW/SH/C	64	Denver, CO
HW/SH/C	15	Kingsville, TX
HW/SH/C	102	Duluth, MN
HW	53	Louisville, KY
HW/SH	72	South Bend, IN
HW	63	Lafayette, IN
HW/SH	25	Gainesville, FL
HW	33	Fresno, CA
HW	73	Peoria, IL
HW/SH	62	Columbus, OH
HW	44	Atlanta, GA
HW/SH/C	24	Baton Rouge, LA
HW	24	Baton Rouge, LA
HW/SH/C	35	Dallas, TX
HW	35	Dallas, TX
HW/SH/C	16	Miami, FL

Table VII. Preferred Installation Sequence (Continued)

TYPE	ZONE	LOCATION
HW	34	Tuscaloosa, AL
HW/SH	52	Blacksburg, VA
HW/SH	82	Milwaukee, WI
HW	83	Madison, WI
HW	51	Seattle, WA
HW/SH/C	51	Seattle, WA
HW/SH	93	Fargo, ND
HW	64	Denver, CO
HW	15	Kingsville, TX
HW/SH	102	Duluth, MN
HW/SH/C	53	Louisville, KY
HW	72	South Bend, IN
HW/SH/C	63	Lafayette, IN
HW/SH/C	25	Gainesville, FL
HW/SH/C	33	Fresno, CA
HW	62	Columbus, OH
HW/SH/C	44	Atlanta, GA
HW/SH/C	52	Blacksburg, VA
HW	82	Milwaukee, WI
HW	93	Fargo, IN

UTILITY RATE REFERENCES

In the standard cost model used for all cost comparisons, the electric utility rates were derived from the following 1973 Federal Power Commission Reports:

1) Statistics of Publicly Owned Electric Utilities in the United states - 1973, S248, December 1974.

2) Statistics of Privately Owned Electric Utilities in the United States - 1973, Classes A and B Companies, S247, July 1975.

APPENDIX

THE KEPNER-TREGOE DECISION ANALYSIS TECHNIQUE

Introduction

Site evaluation and/or selection for solar energy system application should be accomplished in a consistent objective manner. Considerations influencing these decisions are often innumerable and of varying importance. Further complication of the decision process occurs when the desirability of solution alternatives must also be included. Frequently, the mental fact-sorting process is pushed to the limit or exceeded. It is not uncommon to hear the comment, "We were right for the wrong reasons."

Excluding emotion, a functional sequence describing the mental process for decision-making is as follows:

- Recognize a need for decision
- Define possible solutions (alternatives)
- Evaluate suitability of each alternative
- Choose optimum alternative

This process is generally true for short or long term contemplation; however, as the elements involved increase in quantity and complexity, and vary in influence, the process becomes too difficult for mental management. To handle more demanding decisions, the analyst must have a system which provides both analytical consistency in data evaluation and the mechanics for meaningful summarization for alternative choice.

The decision analysis technique described here does not relieve the analyst of any investigative or analytical effort. It does, however, present a systematic approach to alternative selection. If properly utilized, this method should help insure that the rationale for a decision will include all valid considerations to a degree proportional to importance.

The purpose of this paper is to explain this process in a manner that will permit its application to complex multi-consideration situations.

The Kepner-Tregoe Method

Kepner and Tregoe have formalized the process by which a decision-maker selects the "best" strategy, or alternative, from a set of strategies which all satisfy another set of constraints, or objectives. Principles and philosophy of decision theory are well covered in operations research literature. Basically, Kepner and Tregoe satisfy the elements of decision theory by quantifying the abstract, subjective variables upon which the decision-maker bases his selection process. They do this by breaking the selection process down into seven sequential steps, or procedures:

(1) Set objectives against which to choose.

(2) Classify objectives as to importance.

(3) Develop alternatives from which to choose.

(4) Evaluate alternatives against objectives to make a choice.

(5) Chooose the best alternative as a tentative solution.

(6) Assess adverse consequences arising from tentative solution.

(7) Control effects of final solution.

Obviously, there is in Kepner-Tregoe no guarantee of eliminating risk or uncertainty. The "weighting" of Step 2 and the "scoring" of Step 4 are still subjective. But the very act of quantifying these "weights" and "scores" forces the decision-maker into in-depth analyses which reduce, if not preclude, the probability of selecting a suboptimal solution. Now let's look at each of the seven steps in detail.

Set Objectives

Kepner-Tregoe divides objectives into two categories: "must" and "want."

Most "must" objectives will be established for the decision-maker by the customer in his RFP, RFQ, TD, etc. Certainly, all alternatives will satisfy all of these objectives; otherwise, your final selection will be non-responsive.

The "want" objectives are a little more nebulous. Some of them may be detailed in the RFP. Others may be derived from diverse sources: personal contact with the customer; detailed knowledge of the customer's applications; current state-of-the-art developments; etc.

Classify Objectives

The subjectivity of this step in the procedure cannot be denied; at least, as far as the "want" objectives are concerned. Of course, the "must" objectives need not be ranked. As the name implies, they shall be satisfied!

Several algorithms are available from operations research to aid in ranking the "want" objectives. Two that immediately come to mind are the "ranking of goals" and "standard gamble" techniques. The specific algorithm chosen is immaterial as long as you can convince the customer of the validity of the derived ranks or weighting factors.

Develop Alternatives

This step imposes detailed, in-depth analyses of "must" and "want" objectives to assure that tentative system/subsystem/black box configurations meet all customer requirements. No help from operations research or any other similar discipline applies here. A sound engineering background and sheer hard work are the only recourse.

Evaluate Alternatives

Like Step 2, this process is purely subjective. Unlike Step 2, however, there is no existing algorithm to resort to in the derivation of these "scores." The work performed under Step 3, though, should be extremely helpful in introducing the maximum possible objectivity into the subjective situation.

The process, to this point, has generated data that can be most easily depicted in matrix form:

		ALTERNATIVES		
OBJECTIVES	RANK	ALT. 1	ALT. 2	. . . . ALT. N
O_1	R_1	S_{11}	S_{12}	. . . . S_{1N}
O_2	R_2	S_{21}	S_{22}	. . . . S_{2N}
.	.	.	.	. . . . .
.	.	.	.	. . . . .
.	.	.	.	. . . . .
.	.	.	.	. . . . .
O_N	R_N	S_{N1}	S_{N2}	S_{NN}

Choose the Best Alternative

In Kepner-Tregoe, this step is completely "objective." You merely choose the alternative with the highest total score as the tentative solution. The formula used to determine the alternatives scores is:

$$T_J = \sum_{I=1}^{N} R_I S_{IJ} \qquad (J=1,2,\ldots.N)$$

Assess Adverse Consequences

Reluctantly leaving the realm of objectivity, we now consider the Kepner-Tregoe procedure for adversity assessment. By critically examining the potentiality of undesirable consequences arising from the tentative alternative selected by Step 5, and comparing this factor to similar factors derived for one or more of the next-highest ranked potential alternatives, we are able to evaluate the potential-for-success of the tentative solution.

Under Kepner-Tregoe, we must first subjectively define the candidate adverse consequences. One example of this could be that our tentative solution severely pushes the state-of-the-art in a specific area. We must then rank, or weight, these adverse consequences with some arbitrarily chosen numeric values which convey the impact of these variables upon the success of the chosen alternatives. Finally, we assign some probability factor for the occurrence of the defined adverse consequences with respect to each alternative. This activity, too, results in another matrix of the form.

ADVERSE CONSEQUENCE	RANK	WINNERS	
		WINNER 1	WINNER 2
AC_1	R_1	P_{11}	P_{12}
AC_2	R_2	P_{21}	P_{22}
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
AC_N	R_N	P_{N1}	P_{N2}

Having accomplished this, the rest is entirely objective. By applying the following formula, we arrive at the adverse consequence score for each alternative:

$$ACS_J = \sum_{I=1}^{N} R_I P_{IJ} \qquad (J=1,2,\ldots.N)$$

Control Effects

This final step deals entirely with the quantities derived under Steps 5 and 6. The decision-maker must now use his judgment to select a final alternative; one which combines the highest score of Step 5 with the lowest score of Step 6. Ideally, this will result in a selection which is, indeed, optimal.

Computer Solution of the Kepner-Tregoe Algorithm

Step 5 requires a large number of arithmetic operations. While these operations could be easily performed on any desk calculator, the amount of operator time involved, and the potential for operator error, indicate that a computerized solution of the algorithm is highly desirable. This not only reduces the occurrence of error in the final solution to zero; it also allows for manipulations of the data which would be difficult, if not impossible, on a desk calculator.

APL Chosen

The APL (A Programming Language) system of programming was chosen to implement computer processing of the Kepner-Tregoe algorithm for several reasons, the prime reason being that APL is a terminal-oriented, conversational system. This particular feature allows anyone who can read and type to access the programs required. APL also gives us access to more than 77,000 bytes of core and disk for program and data storage.

Sensitivity Analysis

Computerization of the algorithm also resulted in a feature that has considerable import to a user, namely, sensitivity analysis. The programs contain the feature for a unit variance in both weighting factors and scores, which result in the exact assessment of the sensitivity of the data to perturbations. This gives the user a valuable insight into which objectives and/or alternatives are most subject to fluctuation.

Modifications to the Kepner-Tregoe Algorithm

We have assumed the License to modify the Kepner-Tregoe algorithm in two areas. Each modification was designed for a specific purpose and is detailed below

Confidence Factor Modification

Application of the standard Kepner-Tregoe algorithm to a proposal problem revealed one area for modification. This particular user had reservations about the quantities he was supplying for the alternative scores. He felt more confident about the quantities he supplied if we could accommodate a bias factor to increase the leeway available to him (e.g., scores of 9 ± 5%; 8 ± 3%; etc.). We eased his qualms by adding a confidence factor feature to the alternative scores calculation. By converting his percent deviations to confidence factors (e.g., 100% deviation), we were able to calculate ranges for each tentative solution score (i.e., range = RSS of scores times % deviation) and also the probability (i.e., product of the confidence factors) of the calculated scores' occurrence. The range calculations emphasize areas of overlap between the potential "winners" and the probability calculations lend added confidence to "winner" selection. The following, hypothetical example illustrates this feature:

OBJECTIVE	RANK	ALTERNATIVES					
		ALT. 1		ALT. 2		ALT. 3	
ACCESS TIME	8	8	± 5%	6	± 9%	7	± 2%
FLEXIBILITY	6	10	± 1%	7	± 2%	3	± 4%
RELIABILITY	9	7	± 3%	7	± 3%	9	± 2%
ADAPTABILITY	6	10	± 1%	4	± 1%	2	± 6%
COST	10	5	± 6%	9	± 4%	4	± 5%

INPUT DATA SHEET

	ALTERNATE 1	ALTERNATE 2	ALTERNATE 3
ACCESS TIME	64	48	56
FLEXIBILITY	60	42	18
RELIABILITY	63	63	81
ADAPTABILITY	60	24	12
COST	50	90	40
GRAND TOTALS	297	267	207
RANGE (+ OR -)	4.9	6.0	3.0
PROBABILITY	.85	.82	.82

WHERE:

ALTERNATE 1 IS: ALT. 1

ALTERNATE 2 IS: ALT. 2

ALTERNATE 3 IS: ALT. 3