DOE/CE-0048
Dist. Category UC-60

WIND ENERGY SYSTEMS

PROGRAM SUMMARY

Fiscal Years 1981 and 1982

U.S. Department of Energy
Assistant Secretary, Conservation and Renewable Energy
Office of Solar Electric Technologies
Wind Energy Technology Division
Washington, D.C. 20585

January 1983

Appendix A
Project Summaries

This appendix contains a summary sheet on each project funded by DOE in FY 1981 and 1982. However, project funding shown on project data sheets may include allocated prior-year funds. The number of the program element to which each project belongs appears in the upper right-hand corner. The index below explains the numbering system.

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1.1 Economic Analysis

Project Title

Wind System Value Analysis in Selected Utilities

Management SERI David Percival/Susan Hock (303) 231-1471	**CONTRACT NO.** EG-77-C-01-4042
Contractor Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	***Period of Performance*** September 1979 to September 1983 ***FY 81 Funding*** FY 82 Funding $65,000 $65,000
Principal Investigator David Percival/Susan Hock (303) 231-1471	**CUMULATIVE FUNDING** $1,222,000
WORK LOCATION Golden, Colorado	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The value of Wind Energy to electric utilities is uncertain. It depends heavily on the available wind resource, and the utility's generation system mix. This project performs site studies to determine specific results. This project also examines previous value studies to summarize the methodologies and identify remaining issues to be resolved, and to normalize and interpret the results.

OBJECTIVE

Determine the value of WECS at specific sites in relationship to system mix of selected utilities, using the 16 candidate sites for DOE turbine testing, and previous value studies.

APPROACH

The 16 sites are split between two subcontractors. Two sites were studied by both subcontractors and SERI, each using their methodology, so the results can be compared. The remaining sites are split between the two subcontractors. SERI also is summarizing, normalizing and interpreting the results of previous value studies.

OUTPUT

- Each subcontractor and SERI produced a methodology report
- Draft reports on each site will be submitted by both subcontractors
- Each subcontractor will provide a composite report covering all sites and drawing inferences about general factors of WECS value to utilities
- A comparison report investigating the three methodologies and their results on the two common site studies
- SERI will publish a report summarizing the value analysis methodologies of previous studies, and presenting their results in a normalized form (using standard economic assumptions) to allow direct comparisons across studies.

PUBLICATION:

- Sullivan, R.L., Flaim, Theresa, Percival, David. "WECS Value Analysis: A Comparative Assessment of Four Methods," SERI/TR-211-1563, March 1982.

1.1 Economic Analysis

Project Title

Value of Wind Energy Conversion Systems for Specific Utility Systems

Management Susan Hock (303)231-1471 Solar Energy Research Institute	**CONTRACT NO.** XH-9-8336-2
Contractor JBF Scientific Corporation 2 Jewel Drive Wilmington, Mass. 01887	***Period of Performance*** 11/79 - 12/82
	FY 81 Funding FY82 Funding $406,000 -0-
Principal Investigator Thomas F. McCabe (617)657-4170	**CUMULATIVE FUNDING** $540,013
WORK LOCATION Wilmington, Mass.	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The value of wind energy to electric utilities is uncertain, and depends heavily on site-specific parameters such as wind resource and generation mix. This project performs site studies to determine the influence of different operating environments on the value of WECS in specific utility systems.

OBJECTIVE

Determine the value of WECS at specific sites in relationship to system mix of selected utilities.

APPROACH

The value analysis was performed for 10 of the original 16 candidate MOD-0 sites, using recorded wind regime data and generation mix information from the utilities involved.

OUTPUT

- A methodology report.
- Draft reports on each site study
- A composite report covering all sites and drawing inferences about general factors of WECS value to utilities

PUBLICATION:

- JBF Scientific Corporation. "The Value of Wind Energy Conversion Systems for Specific Electric Utilities," September 1981.

1.1 Economic Analysis

Project Title

Value of Wind Energy Conversion Systems for Specific Utility Systems

Management David Percival (303) 231-1263 Solar Energy Research Institute	**CONTRACT NO.** XH-9-8336-1
Contractor The Aerospace Corporation P.O. Box 92957 Los Angeles, California 90009	***Period of Performance*** November 1979 to January 1982
	FY 81 Funding FY 82 Funding $177,300 -0-
Principal Investigator Leon Bush (213) 648-5300	**CUMULATIVE FUNDING** $351,003
WORK LOCATION Los Angeles, California	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The value of Wind Energy to electric utilities is uncertain, and depends heavily on site-specific parameters such as wind resource and generation mix. This project performs site studies to determine the influence of different operating environments on the value of WECS in specific utility systems.

OBJECTIVE

Determine the value of WECS at specific sites in relationship to system mix of selected utilities.

APPROACH

The value analysis was performed for two of the 16 candidate sites for DOE turbine testing, using recorded wind regime data and generation mix information from the utilities involved.

OUTPUT

- A methodology report
- Draft reports on each site study
- A composite report covering all sites and drawing inferences about general factors of WECS value to utilities

PUBLICATIONS:

- The Aerospace Corporation, "Electric Utility Value Analysis Methodology for Wind Energy Conversion Systems," September 1981.
- The Aerospace Corporation, "Electric Utility Value Analysis for Wind Energy Conversion Systems," April 1982.

1.1 Economic Analysis

Project Title

WECS Performance Analysis

Management Martin J.Deutsch (SERI) (303)231-7085	**CONTRACT NO.** EG-77-C-01-4042
Contractor Solar Energy Research Institute 1617 Cole Blvd. Golden, Co 80401 (303) 231-7085	***Period of Performance*** October 1, 1980 to September 30, 1981
	FY 81 Funding $316,000 — FY82 Funding 0
Principal Investigator Martin J.Deutsch (303)231-7085	**CUMULATIVE FUNDING** $996,000
WORK LOCATION Golden, Colorado	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

This task is the redirection of the WECS Market Characterization work started in FY80 to a performance and economic analysis. The need to develop and validate a WECS performance and economic analysis model, collect appropriate data to run the model, and evaluate a pilot region of the country to support inter-connected systems analysis studies for the WECS industry and DOE prompted this investigation.

OBJECTIVE

Develop a WECS performance and economic analysis model for installation on the SERI computer system and determine the economic potential of wind turbines in DOE Region V (Great Lakes).

APPROACH

Develop a county-level wind resource prediction model for the Great Lakes Region; collect a data base of demographics, utility rates, WECS performance and costs, load profiles and state incentives for the region; develop a computerized performance and economic analysis model to operate on all the data bases; and perform a detailed WECS economic analysis at the county level.

OUTPUT

Document the methodology and results in subcontractor final reports for distribution to the WECS industry. Documentation of the SERI Wind Energy Conversion System Analysis Model (WECSAM) computer program and the tapes will be made available to industry through Argonne National Laboratory's National Energy Software Center. Reports to be published are:

Groveman, B.S.; and Easterly, J.L., PRC Systems Service Company. "County-Level Wind Resource Estimates for DOE Region V", SERI/STR-214-1708. March 1983.
Downey, W.T., Arthur D.Little, Inc., "Economic Analysis of Wind Turbines in DOE Region V (Great Lakes)", SERI/TR-19136-4A. March 1983.
Downey, W.T.; and Hendrick, P.L., Arthur D.Little, Inc., "Wind Energy Conversion System Analysis Model (WECSAM) Computer Program Documentation." SERI/SP-19136-4, July 1982.

1.2 Operations and Applications Requirements

Project Title

WECS Applications in Non-Generating Utilities

Management Theresa Flaim (303) 231-7136 Solar Energy Research Institute	**CONTRACT NO.** XZ-1-1025-1
Contractor Regional Systems Services Group, Inc. 5680 South Syracuse Circle Suite 514 Englewood, Colorado 80111	***Period of Performance*** March 5, 1979 to April 30, 1980 and October 1, 1981 to June 30, 1983
	FY 81 Funding $90,000 FY 82 Funding -0-
Principal Investigator Wayne Stafford (303) 770-5010	**CUMULATIVE FUNDING** $229,000
WORK LOCATION Englewood, Colorado	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Many studies have assessed the impact of WECS on generating utilities. However, non-generating utilities (including rural electric cooperatives) serve most of the land area that is suited for WECS installations. Virtually no studies have assessed the impact of WECS on non-generating utilities, and their customers.

OBJECTIVE

The objective is to develop and apply a methodology that can be used to assess the value of WECS to non-generating utilities and their customers and to estimate the impact of customer-owned WECS on the utility.

APPROACH

The methodology will be capable of determining: (1) the output from the WECS, (2) the change in the customer's electric bill and the value of the WECS to the customer, (3) the value of WECS owned by the utility, and (4) the financial impact on the utility resulting from many customer installations of WECS. The methodology will be applied to a case study analysis of a rural electric cooperative.

OUTPUT

The output will be a report that describes the methodology and that summarizes the results obtained from the case study analyzed. The draft report was completed in June 1982 - the final should be published in 1983.

1.3 Institutional/Environmental Analysis

Project Title

Empirical Validation of Selected Testing and Design Parameters

Management Rockwell International J. V. Stafford (303) 497-7159	**CONTRACT NO.** DOE Cooperative Agreement
Contractor American Wind Energy Association 2010 Massachusetts Ave., NW 4th Floor Washington, DC 20036	***Period of Performance*** October 1, 1980 - September 30, 1982 ***FY 81 Funding*** $380,000 ***FY 82 Funding*** $141,000
Principal Investigator Thomas Gray (202) 775-8910	**CUMULATIVE FUNDING** $881,000
WORK LOCATION Contractor's Facility	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

A major obstacle to the development and improvement of small wind energy conversion systems (SWECS) is the lack of standards for testing, performance, safety, and reliability. Research is needed to identify the technical and engineering requirements for SWECS design and performance now being demanded by utilities, public utility commissions, and state and local permitting authorities.

OBJECTIVE

To provide the basis for improved SWECS technology through the evaluation of safety and reliability problems and assure that Rocky Flats testing and design parameters comply with existing recommended practices.

APPROACH

Drawing on its experience with SWECS testing and development, RF assisted DOE/RFAO during FY 1981 in providing technical guidance to industry in standard development. The American Wind Energy Association (AWEA) has instituted standards subcommittees in nine technical areas (interim qualifications, performance, terminology, siting, electrical subsystems, design, certification/labeling, installation, and safety). During FY 1982, AWEA provided Rocky Flats with information required to guide test procedures and research as an interim measure prior to final standards.

OUTPUT

A study was conducted during the last quarter of FY 1980 and report was prepared on the impact of standards, The Impact of Alternative Small Wind Systems Standards Development Scenarios (RFP-3273). During FY 1981, AWEA issued balloted interim standards, and standards for certification and labeling, design, installation, electrical subsystems, and safety. During FY 1982, these documents, together with RF/industry consultations, were employed at Rocky Flats in an evaluation of test procedures and were subjected to validation in the course of ongoing tests and analytical design efforts.

1.3 Institutional/Environmental Analysis

Project Title

WECS Noise Studies

Management SERI Robert Noun (303) 231-1263	**CONTRACT NO.** EG-77-C-01-4042
Contractor Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	***Period of Performance*** October 1, 1980 to September 30, 1982
	FY 81 Funding $660,000 FY 82 Funding $350,000
Principal Investigator Neil D. Kelley (303) 231-1013	**CUMULATIVE FUNDING** $1,450,000
WORK LOCATION Golden, Colorado	**CONTRACTING OFFICE** Chicago Operations Office

PROJECT SUMMARY

BACKGROUND

Early experience with acoustic noise from WECS indicated little possibility of community annoyance at distances much beyond 6-8 rotor diameters from the machine; however, later experience with larger machines has shown this is not necessarily the case. The key problems associated with WECS noise have been to determine the dominant physical mechanisms responsible for its generation and potential human annoyance.

OBJECTIVE

Document and quantify the noise associated with the operation of existing large wind turbine designs and identify (1) the principal physical mechanisms responsible for its generation and propagation and (2) any potential impacts.

APPROACH

The dominant noise generating mechanisms will be identified through a synergistic approach utilizing field measurements of full-scale wind turbines, controlled wind-tunnel testing, and through the use of numerical analytical techniques. Representative acoustic data will be gathered on a number of large turbine designs; i.e., horizontal and vertical axis systems, and compared with respect to their primary noise generating mechanisms and potential impacts.

OUTPUT

"Acoustic Noise Associated with the MOD-1 Wind Turbine: Its Source, Impact and Control," SERI TR-635-1166 (Draft release January 1983).

"Acoustic Emissions Associated with the Operation of a Single MOD-2 Wind Turbine: Their Sources and Potential Impact," SERI TR-215-1861 (Draft release January 1983).

"Acoustic Emissions Associated with the Operation of Darrieus-Type Vertical Axis Wind Turbines," (Draft released April 1982).

"Acoustic Measurements of the DOE/NASA MOD-0 Wind Turbine," SERI TR-635-1240," (Draft reviewed and in final preparation).

1.3 Institutional/Environmental Analysis

Project Title

Studies of Television Interference (TVI) from WECS

Management Robert Noun (303-231-1263) Solar Energy Research Inst.	**CONTRACT NO.** EG-77-C-01-4042
Contractor Solar Energy Research Inst. 1617 Cole Boulevard Golden, Colorado 80401	***Period of Performance*** October 1, 1981 to September 30, 1982
	FY 81 Funding $330,000 — FY82 Funding -0-
Principal Investigator Neil D. Kelley (303-231-1013)	**CUMULATIVE FUNDING** $440,000
WORK LOCATION Farmingdale, New York Ann Arbor, Michigan	**CONTRACTING OFFICE** Chicago Operations Office

PROJECT SUMMARY

BACKGROUND

Wind turbines incorporate rotors which contain two or more blades with an airfoil shape similar to the wings of an aircraft. Previous studies have confirmed low-flying aircraft can cause distortion in television reception and now a similar situation has been found for large wind turbines, which may be more sensitive due to the fixed position nature of WECS.

OBJECTIVE

The objective of the work is to extend previous efforts specifically to assess the level of TVI associated with the MOD-2 installation and to address complex terrain effects and the possibility of amelioration by electronic means.

APPROACH

The project will be performed by a subcontractor, the Radiation Laboratory of the University of Michigan, and SERI will act as project coordinator and manager for the effort which involves other agencies participating in the Federal Wind Program. Further, SERI will monitor activities of the Polytechnical Institute of New York in its feasibility investigation of employing phase-lock-electronics technology for WECS-induced TVI suppression.

OUTPUT

Management reports relating to subcontractor activities.

1.3 Institutional/Environmental Analysis

Project Title

Field and Wind Tunnel Measurements of WECS Noise Generation Studies

Management SERI Neil D. Kelley (303) 231-1013	**CONTRACT NO.** XE-1-1015-1
Contractor University of Colorado Department of Mechanical Engineering	***Period of Performance*** December 1980 to May 31, 1982
	FY 81 Funding $15,000 — FY 82 Funding -0-
Principal Investigator William Wainwright (303) 492-7686	**CUMULATIVE FUNDING** $15,000
WORK LOCATION Boulder, Colorado	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Preliminary measurements of the wake generated by a polygonal-shaped WECS support tower has shown the flow to be largely two-dimensional and described as vortex tubes being shed in the lee of the tower. The impulsive-type noise aften observed with the operation of downwind-rotored WECS is hypothesized to be caused by the blades cutting through such vortex structures.

OBJECTIVE

To support measurements to be made by SERI to document the aerodynamic characteristics of lee wakes from WECS support towers and to examine the role of various aerodynamically shaped rotor blades in the noise generation process.

APPROACH

Perform a series of aerodynamic and acoustic measurements of tower wakes and resulting blade interactions of a full-scale, small wind turbine installation. Design and construct several spoiling devices and evaluate their ability to minimize impulsive radiation. Design and construct a series of constant-chord airfoil sections and wind tunnel test them under a definitive set of unsteady forcing conditions to examine the unsteady lift in impulsive noise generation.

OUTPUT

Scientific data set to be used by SERI for the evaluation of noise generation and its amelioration. No formal documents to be completed.

1.3 Institutional/Environmental Analysis

Project Title An Experimental Analysis of the Effects of Wind Turbine Operating Parameters and Wind Stream Properties on Acoustic Noise

Management SERI Neil D. Kelley (303) 231-1013	**CONTRACT NO.** DE-1-1055-1
Contractor Massachusetts Institute of Technology Department of Aeronautics and Astronautics	***Period of Performance*** March 1981 to November 1982 ***FY 81 Funding*** FY 82 Funding $65,000 -0-
Principal Investigator Wesley L. Harris (617) 253-7482	**CUMULATIVE FUNDING** $95,000
WORK LOCATION Cambridge, Massachusetts	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Previous efforts of the MIT Department of Aeronautics and Astronautics under subcontract to SERI have led to the development of a numerical, analytical model of horizontal axis wind turbine noise generation. This model, while reporducing the macro properties of acoustic radiation of large wind turbines, needs more detailed physical mechanisms incorporated for better accuracy.

OBJECTIVE

To develop an enhanced understanding of the effects of wind turbine performance on various aspects of horizontal axis turbine aerodynamic noise generation so they may be incorporated into the existing numerical prediction model.

APPROACH

An experimental program designed to investigate the acoustic effects of changes in the wind stream properties including ground shear profiles, intensity or incident turbulence, wind yaw angle (cross flow), and tower wakes for various geometries on two, three, and four-bladed rotors. The experiments were carried out using scale models in the MIT anechoic wind tunnel facility.

OUTPUT

"Laboratory Measurements of Noise from a Downwind Rotor Horizontal Axis Wind Turbine," (Draft released August 1981). FDRL Report No. 81-4.

"Experimental Results of Acoustic Tests on a 1/53 Scale Model of the MOD-1 Wind Turbine," (Draft released August 1982). FDRL Report No. 82-2.

1.3 Institutional/Environmental Analysis

Project Title

Electromagnetic Interference by Wind Turbines

Management Neil D. Kelley (303-231-1013) Solar Energy Research Inst.	**CONTRACT NO.** XE-1-1246-1
Contractor University of Michigan Radiation Laboratory Department of Electrical and Computer Engineering	***Period of Performance*** August 1981 to December 1982
	FY 81 Funding $94,400 — FY82 Funding -0-
Principal Investigator Thomas B.A. Senior (313-764-0500)	**CUMULATIVE FUNDING** $223,000
WORK LOCATION Ann Arbor, Michigan	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The University of Michigan Radiation Laboratory has been a leader in the research into interference of electromagnetic communication systems by wind turbines since 1978. They have developed a mathematical model of TVI by horizontal-axis wind turbines and preliminary models of TVI associated with the operation of vertical-axis turbines.

OBJECTIVE

Current objectives include the assessment of the TVI associated with the MOD-2 turbine and to develop models for TVI assessment in complex terrain locations as well as when multiple turbines are installed (wind farms).

APPROACH

Assess the TVI associated with the MOD-2 turbine by carrying out on-site measurements at the Goodnoe Hills installation in southern Washington State using locally available television signals. The effects of multiple scattering by a cluster of three MOD-2 turbines will also be investigated. Results of previous investigations of the MOD-OA, MOD-1, and MOD-2 machines will be used to develop complex terrain TVI assessments.

OUTPUT

Final technical report summarizing the results of the MOD-2 assessment for both a single turbine and a cluster of three plus the effects of complex terrain will be incorporated and the draft released during late December 1982.

1.3 Institutional/Environmental Analysis

Project Title	Generic Studies of Sound Propagation Relating to Noise Radiated by Wind Energy Conversion Systems		
Management	Neil D. Kelley (303-231-1013) Solar Energy Research Inst.	**CONTRACT NO.**	XE-1-1138-1
Contractor	The Pennsylvania State University Department of Meteorology	***Period of Performance***	June 1981 to December 1982
		FY 81 Funding	FY82 Funding
		$67,600	-0-
Principal Investigator	Dennis W. Thomson (814-865-0478)	**CUMULATIVE FUNDING**	$108,000
WORK LOCATION	State College, Pennsylania	**CONTRACTING OFFICE**	Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The complaints of annoyance from the operation of the MOD-1 wind turbine, while perhaps being unique to this machine, have pointed out the role of atmospheric propagation of low-frequency acoustic radiation in any future planning for WECS installations. With the trend for the siting of multiple and large WECS, a thorough investigation of WECS noise propagation is necessary.

OBJECTIVE

To develop a set of specific recommendations for meteorologically dependent noise impact evaluations which should be implemented as part of WECS siting analysis.

APPROACH

To expand the work previously supported by a SERI subcontract by modifying existing medium ray-trace software to facilitate analysis of ray trace path trajectories through a horizontally inhomogenous atmosphere and to establish the viability of using image space transformations to define the virtual vertical extent of WECS noise and to simplify and economize the process of determining the temporal and spatial variations of caustic locations.

OUTPUT

Final report will be published in 1983.

1.3 Institutional/Environmental Analysis

Project Title

Suppression of Electromagnetic Interference Caused by Wind Turbine Generators

Management SERI Neil D. Kelley (303) 231-1013	**CONTRACT NO.** XE-1-9387-1
Contractor Polytechnical Institute of New York Microwave Research Institute	***Period of Performance*** December 1980 to December 1981 ***FY 81 Funding*** FY 82 Funding $48,900 -0-
Principal Investigator Frank A. Cassara (516) 694-5500	**CUMULATIVE FUNDING** $48,900
WORK LOCATION Farmingdale, New York	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Electromagnetic interference caused by large wind turbines can cause disturbance of TV video reception. One approach to solving this problem is to develop interference suppression circuits for incorporation in the TV reception system of homes located near the turbine.

OBJECTIVE

To provide important design data leading to the development of an interference-suppression technique which is inexpensive and compatible with current modes of TV transmission and reception.

APPROACH

The capabilities and limitations of cross-coupled, phase-lock-loop technology as used in a television receiver structure in suppressing the type of milti-path distortion introduced by wind turbines will be evaluated through analytical modeling.

OUTPUT

"Suppression of Electromagnetic Interference Caused by Wind Turbine Generators," Final Technical Report No. POLY-MRI-1418-81, Issued December 1981.

1.3 Institutional/Environmental Analysis

Project Title

Analysis of Interface Problems with REC's

Management USDA-ARS R.N. Clark (806) 378-5721	**CONTRACT NO.** DE-AI01-76ET20319
Contractor Regional Systems Services Group, Inc. 5680 South Syracuse Circle Suite 514 Englewood, Colorado 80111	***Period of Performance*** 1 year ***FY 81 Funding*** FY 82 Funding $45,000 -0-
Principal Investigator Wayne Stafford (303) 770-5010	**CUMULATIVE FUNDING** $45,000
WORK LOCATION Englewood, Colorado	**CONTRACTING OFFICE** USDA-ARS, Conservation and Production Research Laboratory, Bushland, Texas

PROJECT SUMMARY

BACKGROUND

There are a number of concerns related to interfacing of co-generated power from SWECS with a utility. Foremost is the safety of personnel working on the utility lines. If a large number of SWECS are interfaced on a given system, problems such as over- or under-voltage, current frequency, harmonics, flicker, and reactive power requirements may occur. Supply systems protection coordination, line or generator tripping, load modeling and stability analysis may become more of a problem, as may possible damage to either utility or customer equipment.

OBJECTIVE

To evaluate and determine the equipment, techniques and technical problems associated with the interconnection of SWECS to rural electrical power systems.

APPROACH

A RFP was issued and a contract was awarded to determine technical approaches and hardware required for interfacing SWECS to rural electric power systems with particular emphasis on safety, technical feasibility, and metering of SWECS power delivered back to the utility.

OUTPUT

The final report has been written and reviewed, and will be published in 1983.

1.3 Institutional/Environmental Analysis

Project Title

Utility Feeder Saturation Simulation and Analysis

Management Rockwell International A.R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 - September 30, 1981
	FY 81 Funding $339,000 FY 82 Funding -0-
Principal Investigator J.C. Balcerak (303) 497-7139	**CUMULATIVE FUNDING** $339,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Preliminary studies indicate potential economic and electrical impact to utilities at high SWECS cogeneration penetration levels. However, no test data have been gathered to prove this assertion. This project presented a plan to more fully examine the electrical effects of high-penetration level SWECS cogeneration by performing controlled experiments on the 13.2 kV feeder at the Rocky Flats Wind Energy Research Center (WERC).

OBJECTIVE

- o Access the electrical impact of significant SWECS cogeneration on a utility feeder.
- o Develop computer models to predict the effects of SWECS installed on utility feeders.

APPROACH

The 13.2 kV feeder was instrumented to measure system response to the entire WERC source. More controlled tests were performed at the 480-volt level where it is feasible to form an isolated power bus for selected SWECS. A cooperative effort with Public Service Company of Colorado was solicited to install similar instrumentation at their substation for the purpose of evaluating the effect of significant SWECS capacity on a distribution feeder. Portions of the work planned under this project were transferred to a new FY 1982 project, "Electrical Stability, Control, and Performance Improvement."

OUTPUT

Plans were to develop a computer model suitable for predicting steady-state and transient response of a feeder to input from a significant SWECS input. Technical memos were planned to describe load characteristics data useful for future performance testing and determine SWECS penetration levels where system operation is adversely affected.

1.4 Program Development/Planning

Project Title TECHNICAL AND MANAGEMENT SUPPORT TO THE FEDERAL WIND ENERGY PROGRAM

Management DOE/AL/WETPO Mr. G.P. Tennyson (505)846-3219	**CONTRACT NO.** DOE-AC04-78ET04115
Contractor Raytheon Service Company 2 Wayside Road Burlington, MA 01803	**Period of Performance** September 1978-September 1981 **FY 81 Funding** FY 82 Funding $815,000 -0-
Principal Investigator Mr. C.A. Wendell (617)272-9300	**CUMULATIVE FUNDING** $2,080,983
WORK LOCATION Albuquerque, NM; Arlington, VA; Burlington, MA	**CONTRACTING OFFICE** DOE/Albuquerque Operations Office

PROJECT SUMMARY

BACKGROUND

In its active pursuit of the utilization of wind energy conversion systems, DOE incurred a need for a systems contractor to provide management support of the diverse tasks required of contractors and utilities involved in the fabrication, siting, installation, and field testing of experimental wind turbines.

OBJECTIVE

This program was to ensure the necessary systems capability to exercise technical management functions such as planning, specifying, coordinating, monitoring, and reporting the activities of contractors and users with a major goal of minimizing fabrication and installation costs.

APPROACH

Specific tasks to be performed included planning the operations of field-test programs, generating performance parameters, coordinating contractor operations, and assuming responsibility for accuracy and quality of contractor reporting.

OUTPUT

Throughout the course of the contract updated and detailed program schedules costs, and integrated task planning inputs were submitted through regular program reviews and upon specific request. Topical report reviews were submitted as completed.

1.4 Program Development/Planning

Project Title
Wind Energy Industry Analysis

Management Bob Noun (303)231-1263 Solar Energy Research Institute	**CONTRACT NO.** XE-1-1127-1
Contractor The Synectics Group, Inc. 1730 17th Street., NW Washington, DC 20036	***Period of Performance*** March 23, 1981 to March 31, 1982
	FY 81 Funding $40,000 — FY82 Funding $60,000
Principal Investigator Michael Lotker (202)887-0970	**CUMULATIVE FUNDING** $100,000
WORK LOCATION Washington, D.C.	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The Wind Energy Systems Act of 1980 required DOE to assess the U.S. wind energy industry to determine the need and nature of future federal government research activities in the wind energy field.

OBJECTIVE

Assess the status of the wind energy industry as of the end of 1981 to determine future DOE research needs and actions.

APPROACH

Conduct an analysis of the wind energy industry through discussions with WECS manufacturers and distributors, utilities, financial institutions and government officials.

OUTPUT

A report submitted to DOE.

1.4 Program Development/Planning

Project Title

Federal Applications Study

Management (303)231-1939 H. Sklar (SERI) FTS:327-1939	**CONTRACT NO.** XE-1-1160-1
Contractor JBF Scientific Corp. 2 Jewel Drive Wilmington, Massachusetts 01887	***Period of Performance*** December 1980 to October 1981
	FY 81 Funding FY82 Funding $402,460 -0-
Principal Investigator J. Wilson (617)657-4170	**CUMULATIVE FUNDING** $402,460
WORK LOCATION Arlington, Virginia	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The Wind Energy Systems Act of 1980 requires a DOE study and reports on federal applications for wind energy systems.

OBJECTIVE

Evaluate federal applications for wind energy.

APPROACH

Sixteen federal agencies submitted information on 9,288 potential sites. A preliminary economic analysis was performed. 276 sites were submitted for a more detailed analysis using machines selected from a catalogue of representative wind machines developed for the study. Implementation planning guidelines for federal agencies were prepared and two case studies were performed.

OUTPUT

DOE report to Congress: Applications Study for Wind Energy Systems at Federal Facilities" Preliminary Report, July 1981.
DOE report to Congress: "Applications Study for Wind Energy Systems at Federal Facilities" Final Report, January 1982
SERI report: "Federal Applications for Wind Energy Systems", STR-211-1707, August 1982

2.1 Wind Energy Prospecting

Project Title

Resource Assessment

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** October 1977 - September 1981 ***FY 81 Funding*** FY 82 Funding $1,116,000 -0-
Principal Investigator W. R. Barchet (509) 375-3876	**CUMULATIVE FUNDING** $4,827,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Techniques developed for assessing the wind resource were developed by PNL, applied to the Northwest region as a prototype and then applied by other contractors to other regions of the U.S. The work in FY-81 is primarily to conclude the resource assessment activities.

OBJECTIVE

The objectives are to complete the regional wind energy resource atlas for the U.S., a world-wide assessment for the United Nations and organize the resource data used in the regional assessments into a data base.

APPROACH

PNL will continue to monitor the completion of the regional assessments, publish the atlases and synthesize the regional maps into a national map for the U.S. Techniques used in the U.S. assessment will be applied to the world-wide assessment. A data base of wind resource data will be compiled from the statistical analyses of wind data made for the regional assessments and from a digitization of the regional wind resource maps.

OUTPUT

The major products are a completed set of regional wind resource atlases (Wind Energy Resource Atlas: Volumes 1-12, PNL-3195 WERA 1-12, which were published from April 1980 to March 1981) color maps of the U.S. and world-wide wind resources, and a computer data base of wind resources data.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.1 Wind Energy Prospecting

Project Title

Coastal Zone Wind Study

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** B-B-93492-A-Q
Contractor University of Virginia Charlottesville, VA 22903	***Period of Performance*** September 1976 - September 1981
	FY 81 Funding -0- FY 82 Funding -0-
Principal Investigator Dr. M. Garstang (804) 977-3733	**CUMULATIVE FUNDING** $298,000
WORK LOCATION Charlottesville, Virginia	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

In previous years this project has developed a climatology of the wind resource along the East and Gulf coast areas through an evaluation of the climatology of various weather patterns and the application of numerical modeling techniques. A field program to obtain verification of model predictions was also carried out.

OBJECTIVE

The objectives in FY 1981 are to complete the numerical simulation of the wind resource over the three study areas and to do a detailed comparison of the model results with the field experiment data.

APPROACH

Numerical model estimates of the wind resource during dominant weather patterns are combined to yield a wind resource estimate. Data from a brief but intense measurement program will be used to verify model results and estimate the utility of this approach to evaluating the wind resource.

OUTPUT

Coastal Wind Energy. Part II: Validation of the Coastal Zone Wind Power Potential - A summary of the Field Experiment, PNL-3904, June 1980,

Coastal Zone Wind Energy. Part III: A Procedure to Determine the Wind Power Potential of the Coastal Zone, PNL-3903, March 1982.

A Comparison of Model Predicted to Observed Winds in the Coastal Zone, PNL-3714, July 1982.

2.1 Wind Energy Prospecting

Project Title

Synoptic Climatology of Wind Resource

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** B-C-3097-A-N
Contractor University of Virginia Charlottesville, VA 22903	***Period of Performance*** March 1981 - September 1981
	FY 81 Funding FY 82 Funding $83,000 -0-
Principal Investigator Dr. M. Garstang (804) 977-3733	**CUMULATIVE FUNDING** $83,000
WORK LOCATION Charlottesville, Virginia	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

Results of an analysis of the wind resource in the coastal zone by this contractor have shown the usefulness of a climatology of weather pattern types for evaluating the meteorological mechanisms driving the observed wind resource. Further a climatology of weather pattern types can be used to compare one period of observation to another and may help in making long-term estimates of the wind resource or energy production from a short period of observation.

OBJECTIVE

The objective is to produce a time series of weather patterns over the Great Plains major wind resource region and evaluate the synoptic climatology.

APPROACH

An approach similar to that taken in the study of the coastal wind resource will be applied to the Great Plains area. Eight distinct weather pattern types or positions relative to major air masses and fronts will be defined. Weather maps for a 10 year period--1955 to 1964--will be analyzed for weather pattern type at 62 Great Plains locations.

OUTPUT

The primary output is a data tape containing a time series of weather pattern types at the 62 Great Plains locations and a brief report describing how the analyses were done. The data tape will be used in a continuation study in FY-82 that merges wind data with the weather patterns to create a wind climatology stratified by weather pattern type.

2.1 Wind Energy Prospecting

Project Title

Site Selection Techniques

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** October 1977 - September 1981 ***FY 81 Funding*** FY 82 Funding $399,000 -0-
Principal Investigator T. R. Hiester (509) 375-3870	**CUMULATIVE FUNDING** $3,454,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Unlike resource assessment, which considers large scale features of the wind resource, siting focuses on the wind characteristics of a localized area. The physical characteristics indicative of a good wind turbine site and the wind characteristics that need to be measured to determine the potential of a site are addressed in this technical area of the program.

OBJECTIVE

The objectives are to develop, verify and demonstrate techniques and strategies for identifying sites favorable for the utilization of wind energy and to document and disseminate this information in a user-oriented format.

APPROACH

Numerous subcontractors have explored and developed site identification and evaluation techniques. Equally as important to developing these diverse techniques, findings and methodologies is their integration into user-oriented documents and presentations. Siting handbooks have been prepared for both the small and large wind turbine user and a short course on turbine siting is in preparation.

OUTPUT

The principal products were user-oriented documents such as siting handbooks, short courses and reports on specific topics related to the problem of site selection.

* Includes Subcontractor's costs and PNL Subtask costs shown on subsequent pages.

2.1 Wind Energy Prospecting

Project Title

Siting Handbook for Large Wind Turbines

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** January 1979 - January 1981 ***FY 81 Funding*** FY 82 Funding $32,000 -0-
Principal Investigator W. T. Pennell (509) 375-3870	**CUMULATIVE FUNDING** $219,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Site selection and evaluation for the installation of large wind turbines, singly or in clusters involves an investment of sufficient magnitude to warrant a detailed study of meteorological aspects of the site.

OBJECTIVE

The objective is to present a siting strategy for large wind turbines that will minimize the chance of selecting an unproductive site.

APPROACH

The approach is to review DOE sponsored siting studies and give a critical evaluation of their recommendations and techniques. Then a strategy for site selection, evaluation and development is presented to inform utility technical personnel, engineering consultants and others involved in turbine siting decision of the appropriate steps to take in selecting turbine sites.

OUTPUT

A report, Meteorological Aspects of Siting Large Wind Turbines, PNL-2522, was published in January 1981.

2.1 Wind Energy Prospecting

Project Title

Wind Shear in the Nocturnal Boundary Layer

Management Pacific Northwest Laboratory L.L. Wendell (509) 375-3870	**CONTRACT NO.** DE-A106-ET23116
Contractor Oregon State University Corvallis, Oregon 97331	***Period of Performance*** February 1979 - September 1981
	FY 81 Funding -0- FY 82 Funding -0-
Principal Investigator L. J. Marht (503) 754-4557	**CUMULATIVE FUNDING** $61,000
WORK LOCATION Corvallis, Oregon	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Strong nocturnal wind shears are frequent over the high plains region since strong radiational cooling causes the boundary layer to be thin and the nocturnal jet low. These shears are roughly a factor of two larger than those predicted by the 1/7 power law. With baroclinic contributions they can exceed the shears predicted from conventional frictional-inertial theory by an order of magnitude. Such large shears can lead to excessive wind machine fatigue; therefore, an understanding of the frequency and characteristics of nocturnal shears is necessary for WECS design. Diurnal wind power variations by season and geographical location are appropriate considerations for both WECS design and siting.

OBJECTIVE

To provide a description of the characteristics of the vertical variation of the horizontal wind in the nighttime boundary layer.

APPROACH

Data from Colorado, Oklahoma, Nebraska, the Pacific Northwest, Australia and Denmark were analyzed. Cumulative frequency distributions for velocity shears in the vertical were computed for layers appropriate to WECS for different time of day, season and geographic location. Similarly, variations in wind power were computed. Preliminary attempts to identify a simple parameter set with which to model these shears was made.

OUTPUT

A report, Analysis of Strong Nocturnal Shears for Wind Machine Design (DOE/ET/23116-80/1), which characterizes the "vertical wind shear" of the nocturnal boundary layer at a number of specific measurements sites, was published in November 1980. Also found in the report are estimates of both the duration and horizontal distribution of the characterized, anomalous boundary layer.

2.1 Wind Energy Prospecting

Project Title

Remote Observations of Wind Indicators

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** B-92627-A-H
Contractor Oregon State University Corvallis, OR 97331	***Period of Performance*** October 1980 - September 1981
	FY 81 Funding FY 82 Funding $70,000 -0-
Principal Investigator J. E. Wade (503) 754-4557	**CUMULATIVE FUNDING** $70,000
WORK LOCATION Corvallis, Oregon	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

Many indirect indicators of strong and persistent winds have recently been developed or explored as tools in wind energy prospecting: wind deformed vegetation, migrating sand dunes, blowing sand or snow, waves. These indicators can often be detected on satellite imagery or aerial photographs or observed at close range.

OBJECTIVE

The objective is to demonstrate how to use remotely observable indirect indicators of high wind areas for wind energy prospecting.

APPROACH

A top down approach is taken to observing and interpreting indirect indicators of high wind energy. The search for such indicators begins with satellite imagery then high altitude aerial photography, progresses to low altitude aerial photography and concludes with onsite observation and measurements. At each scale the appearance of the indicators is discussed and interpreted. Three case studies of application of the techniques will be included.

OUTPUT

A report, Remote Sensing for Wind Power Potential, A Prospector's Handbook, DOE/ET/20316-81/1, will document the use of remote sensing platforms for wind prospecting. This report was published in FY 82.

2.1 Wind Energy Prospecting

Project Title

Small-Scale Terrain Effects

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76ET20242
Contractor FWG Associates, Inc. RR #3 Box 331 Tullahoma, TN 37388	***Period of Performance*** August 1976 - September 1981 ***FY 81 Funding*** FY 82 Funding $2,000 -0-
Principal Investigator Dr. W. Frost (615) 455-1982	**CUMULATIVE FUNDING** $306,000
WORK LOCATION Tullahoma, Tennessee	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

An issue of considerable interest to those siting small wind turbines is the importance of local or nearby topographic features. The long range activities have focused on formulating guidelines and rules of thumb which can be used to site wind turbines relative to small terrain features.

OBJECTIVE

The objectives in FY-81 are to complete a handbook of guidelines for siting relative to terrain and, in a supplemental task, to analyze the response of kite anemometers to the mean and turbulent wind.

APPROACH

The nearly complete handbook is a compilation of existing knowledge in fluid mechanics and meteorology of flow over and around two- and three-dimensional obstacles. The kite anemometer analysis applies aerodynamic principles and free body diagrams to derive equations of motion for the kite-tether system. A linearized set of equations is solved numerically for various Fourier components to deal with the mean and turbulent component of the wind.

OUTPUT

Two reports were published: Guidelines for Siting WECS Relative to Small Scale Terrain Features, DOE/ET.20242-81/1, and Analysis of Kite Anemometer, DOE/ET/20242-81/2, were published in June 1980 and December 1981. The kite anemometer analysis has shown that mean tether tension is well correlated to the mean wind speed, that wind shear has a nearly insignificant effect on tether tension and that tether tension is in phase with the turbulence of the wind at the kite.

2.2 Support for Design and Operations

Project Title

Meteorological Characteristics for Design and Evaluation

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland,WA 99352	***Period of Performance*** October 1976 - September 1981 ***FY 81 Funding*** FY 82 Funding $650,000 -0-
Principal Investigator J. R. Connell (509) 375-3879	**CUMULATIVE FUNDING** $2,881,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND Early research into wind effects on turbine stresses and fatigue life focused on gust probabilities derived from single point or single tower measurements. Exploratory research including modeling and measurements was conducted to find the type of wind information most relevant to wind turbine design. Preliminary results from an early field program, in which wind measurements were made with a vertically oriented circular array of anemometers, indicated the importance of rotationally sampling the wind.

OBJECTIVE

To develop the measurement techniques to provide the appropriate wind data for turbulence analyses and model development needed for producing reliable input to design stress calculations.

APPROACH

The testing and reporting was completed for a model of the response of a hypothetical wind turbine to atmospheric turbulence including in-plane components and to variations across the disc. A model of the turbulence spectrum for rotationally sampled wind was developed and tested with wind measurements from the vertical plane array at PNL. The acquisition and installation of towers for an array at the MOD-0A site at Clayton, New Mexico was completed and wind data acquisition was initiated.

OUTPUT

The results of this research area are published in reports on in journal articles which are referenced on the individual project sheets.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.2 Support for Design and Operations

Project Title

Wind Characteristics for Advanced Design of Wind Turbines

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AM06-76RL02227
Contractor Oregon State University Corvallis, OR 97331	***Period of Performance*** July 1979 - September 1981
	FY 81 Funding FY 82 Funding $8,000 -0-
Principal Investigator R. W. Thresher (503) 754-2535	**CUMULATIVE FUNDING** $138,000
WORK LOCATION Corvallis, Oregon	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

The methods for computing the loads and dynamic responses due to atmospheric turbulence for current large wind turbines reduce the turbulence input to a deterministic discrete gust which totally engulfs the rotor. Further, turbine loads are computed using this deterministic gust as input.

OBJECTIVE

To determine what wind characteristics are important for advanced design of wind energy conversion systems.

APPROACH

It has been the goal of this research to develop an alternate analysis technique for determining the influences of excitations due to atmospheric turbulence. The approach has been to treat both wind characteristics inputs and resulting loads using statistical methods which provide more insight into the basic physics of wind response characteristics of wind turbines.

OUTPUT

The goal of the research was to determine which of the excitation sources in the atmospheric turbulence are important in characterizing the wind turbine system responses. In many earlier studies, turbulence is modeled simply as one component along the mean wind which acts uniformly across the rotor disk. This work established the sensitivity of the system responses to the in-plane turbulent velocity components and to variations across the rotor disk. Two reports were published in October 1982. The Response Sensitivity of Wind Turbines to Atmospheric Turbulence (DOE/ET/23114-81/1) and Modeling the Response of Wind Turbines to Atmospheric Turbulence (DOE/ET/23114-81/2).

2.2 Support for Design and Operations

Project Title

Flow Through a Vertical Plane - Rotational Analysis

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** January 1977 - September 1981 ***FY 81 Funding*** FY 82 Funding $40,000 -0-
Principal Investigator J. R. Connell (509) 375-3879	**CUMULATIVE FUNDING** $294,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Investigations of the spectra of turbulence are historically based on single point measurements. The power spectral density of wind speed fluctuations along and across the flow of wind fairly will describe the nature of turbulence in a horizontal plane but translation of a series of planes by a sensor rotating about a horizontal axis would appear to be in a different atmosphere altogether.

OBJECTIVE

To extend previous spectral and gust analyses of a single case of moderate winds sampled rotationally around the vertical plane array at PNL to include additional wind cases. To improve the statistical estimate of the characteristics of wind sampled rotationally along a vertical circle.

APPROACH

A simple theoretical model of the spectrum of turbulence which is rotationally sampled is developed. The model which assumes homogeneous, isotropic turbulence, reproduces the shape of the spectrum as observed independently including the general decrease in energy around 0.1 Hz and a subsequent increase above the 1 P speed and in other eigenfrequencies up to at least 4 P.

OUTPUT

This research effort has been successful in demonstrating the existence and quantitative nature of the distortion of wind velocity variations in time when viewed from a rotational aspect. A report entitled, The Spectrum of Wind Speed Fluctuations Seen by a Rotating Blade of a Wind Energy Conversion System, PNL-4083, was published in November 1981.

2.2 Support for Design and Operations

Project Title

Wind Direction Variability

Management Pacific Northwest Laboratory L. L. Wendell (509)375-3870	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1980 - September 1981 ***FY 81 Funding*** FY 82 Funding $91,000 -0-
Principal Investigator D. C. Powell (509) 375-3888	**CUMULATIVE FUNDING** $91,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Wind turbine yaw stratgies must be formulated with appropriate knowledge of the probabilistic and spectral character of wind direction fluctuations that pertain to the frequency range of machine sensitivity. Also machine fatigue is partially a function of the same character of wind direction fluctuations, which had not been adequately described owing to previous emphasis on wind speed.

OBJECTIVE

To quantify the probability distribution of wind direction fluctuations and the associated spectral character so that not only the probability but also the duration of directional fluctuations of given magnitude as a function of stability, roughness and machine sensitivity can be estimated.

APPROACH

The required features for the wind directional model were arrived at by using, 1) summarized analysis of 1968 Kansas data, 2) PNL vertical plane array data and, and 3) previously published spectral models for neutral and unstable conditions.

OUTPUT

A report entitled Basic Probability Characteristics of Wind Direction Fluctuations, PNL-4186, was published in May 1982.

2.2 Support for Design and Operations

Project Title
Great Plains Winds

Management Pacific Northwest Laboratory L.L. Wendell (509) 375-3870	**CONTRACT NO.** B-92628-A-N
Contractor Argonne National Laboratories 9700 South Cass Avenue Argonne, IL 60439	***Period of Performance*** October 1980 - September 1981 ***FY 81 Funding*** FY 82 Funding $44,000 -0-
Principal Investigator B. Hicks (312) 739-7711	**CUMULATIVE FUNDING** $44,000
WORK LOCATION Argonne, Illinois	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

One of the most likely regimes where many wind turbines will be placed is the Great Plains. This region has several kinds of strong wind events which occur often. This regime has not been characterized in ways especially useful for WECS design criteria. The analysis of this existing, unique data will provide first estimates of needed wind characteristics at a modest price.

OBJECTIVE

To describe the wind of the "turbine layer" at Norman, Oklahoma using a 1-year record of data already recorded. To compute wind shear fluctuations and PNL gust statistics for wind speed and direction. To describe especially severe wind events such as thunderstorms, squall lines and fronts. To describe nocturnal wind speed maximum events.

APPROACH

A 1-year record of winds measured from a tall meteorological tower at Norman, Oklahoma has been acquired, checked and edited for quality. Existing computer programs will be used to produce wind statistics for design. These cases will be parameterized and stratified on a case study basis in order to put them in a form facilitating application to a wider range of locations in the Great Plains.

OUTPUT

A report characterizing wind shear fluctuations, and gust events using PNL gust models and spectral analyses, "A Comparison of Wind Speed Shears for Frontal and Undisturbed Synoptic Conditions," PNL-SA-10737, will be published in February 1983. Data on digital magnetic tape of a full year of wind and temperature data at 10-sec and 1-sec sampling rates at all heights on a tall meteorological tower for use by any contributor to the DOE/WSB program were also produced.

2.3 Site Evaluation

Project Title

Site Assessment and Development Techniques

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1980 - September 1981 ***FY 81 Funding*** FY 82 Funding $142,000 -0-
Principal Investigator D. S. Renné (509) 375-3890	**CUMULATIVE FUNDING** $142,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Once potentially viable wind sites are identified through resource assessment and site selection techniques, the evaluation of these sites for suitability in installing wind turbine clusters is needed. A number of siting and site evaluation techniques are needed to make this evaluation timely and cost effective.

OBJECTIVE

To develop, verify, and apply techniques for designing wind turbine cluster arrangements and to recommend the meteorological measurements necessary to provide appropriate data for site development decisions.

APPROACH

A wind turbine wake model will be developed with improved treatment of wake turbulence. The sensitivity of wind turbine arrays to variations in meteorological and machine parameters using an upgraded version of the wakes model will be analyzed. Means of shortcutting the currently perceived need for long-term wind profile measurements at a site will be investigated.

OUTPUT

A series of reports documenting climatological adjustment techniques, numerical modeling approaches, and statistical evaluations for use in site evaulation have been published.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title

Climatological Adjustment

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** October 1978 - September 1981 ***FY 81 Funding*** FY 82 Funding $28,000 -0-
Principal Investigator J. V. Ramsdell (509) 375-3854	**CUMULATIVE FUNDING** $77,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Time series of wind data over the period of a year are often needed as input to wind system analyses. Collecting such data at sites of interest is time consuming. This task is the continuation of previous work on methods for making long-term climatological estimates from limited observational data.

OBJECTIVE

The objectives are to develop a methodology for representing the long-term wind time series based on only a short period of observations.

APPROACH

A stochastic model will be developed that will reproduce seasonal and daily variations of the hourly mean speed with the same statistical characteristics as the input wind data. The model will be capable of generating a time series of wind speeds which behaves statistically the same as observed wind, that is has the same mean, variances, and autocorrelations as the real wind.

OUTPUT

A report describing the model, its application and performance, A Numerical Wind Speed Evaluation Model, PNL-3864, was published in September 1981. The model is capable of simulating real winds in a statistical sense by incorporating the time variation of a mean wind, the variance and an auto-correlation. Sinusoids are used to represent the time variation over the annual cycle. Some 21 parameters derivable from observed data are used to set up the model.

2.3 Site Evaluation

Project Title

Cluster Output Sensitivity Study

Management L.L. Wendell (509) 375-3870 Pacific Northwest Laboratory	**CONTRACT NO.** B-C 3021-A-N
Contractor AeroVironment, Inc. 145 Vista Avenue Pasadena, CA 91107	***Period of Performance*** May 1981 - September 1981
	FY 81 Funding FY 82 Funding $50,000 -0-
Principal Investigator P.B.S Lissaman (213) 449-4392	**CUMULATIVE FUNDING** $50,000
WORK LOCATION Pasadena, California	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

The Lissaman array model is used to predict the decrease in wind turbine array efficiencies due to wake interference effects. The key component of the model is the simulation of the wake found downwind of a turbine. Since the initial development of the model, wake data has been obtained from wind tunnel scale and full-scale turbines. An examination of this data has suggested that improvements to the wake simulation are possible.

OBJECTIVE

The objective of this study was to improve the array model. Most of this effort was concentrated in improving the wake simulation.

APPROACH

This work was performed by AeroVironment, Inc. under contract to PNL. Modifications to the wake simulation were guided by a comparison between the experimental data and predictions made by the simulation. The final changes included a reevaluation of the turbulent growth algorithm, the incorporation of the effects of viscous rotor drag, and the use of the transverse component of the turbulent intensity (rather than the scalar component). Changes were also made in the array performance aspect of the model.

OUTPUT

The output of this study was an improved model for calculating array efficiencies. This improved version was applied to some hypothetical turbine array layouts to test the sensitivity of the array efficiency to various parameters, such as turbulent intensity mean wind speed, etc. The model was also applied to the MOD-2 site at Goodnoe Hills and the sensitivity of this particular array was examined. A report entitled Numerical Modeling Sensitivity Analysis of the Performance of Wind Turbine Arrays, PNL-4183, was published in June 1982.

2.3 Site Evaluation

Project Title

Meteorological Validation Program

Management L.L. Wendell (509) 375-3837 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** July 1978 - September 1981
	FY 81 Funding $1,021,000 FY 82 Funding -0-
Principal Investigator D.S. Renne (509) 375-3890	**CUMULATIVE FUNDING** $3,929,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

There is a need for utility participation if effective operation of several prototype large wind turbine systems in typical user environments is to be demonstrated. However, it is unrealistic to expect that all interested utilities will have appropriate onsite wind data for use in determining which sites will receive machines for testing purposes. Collection of onsite data will provide an incentive for utilities to pursue wind energy utilization even if they are not awarded a machine from the federal government.

OBJECTIVE

The objective of this program is to obtain sufficient wind data to accurately assess the wind energy of various sites as an evaluation factor in the selection of sites for future wind turbine installations. The second objective is to continue collection of onsite data at sites where machines are installed, modifying the measurement system to support the R&D effort.

APPROACH

Meteorological towers 150 ft in height have been installed at all candidate sites selected through the RFP released in March 1976 and the PON released in FY 1979. Continuous collection of wind data at two or more levels on the tower will proceed for a long period of time for use in installation site selections. Once a turbine is installed on a site, the measurement program will be modified to collect turbine parameter data to support operational strategies and performance evaluations.

OUTPUT

Data collected at each site was used to prepare monthly data reports. A report entitled Candidate Wind Turbine Generator Site Annual Data Summary for January 1980 Through December 1980, PNL-3739, was published in April 1981.

*Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title

Meteorological Measurements at Candidate Sites

Management L.L. Wendell (509) 375-3837 Pacific Northwest Laboratory	**CONTRACT NO.** B-92790-A-K
Contractor Engineering Sciences P.O. Box 538 Arcadia, CA 91006	***Period of Performance*** January 1980 - June 1981 ***FY 81 Funding*** FY 82 Funding $58,000 -0-
Principal Investigator D. P. Becvar (213) 445-7560	**CUMULATIVE FUNDING** $950,000
WORK LOCATION Arcadia, California & Candidate Sites	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

Since 1976, meteorological data have been collected at sites around the U.S. for further documentation as to the suitability for testing large wind turbines. During FY 1981 an additional 19 new sites, which were installed beginning in FY 1980, were acquiring data.

OBJECTIVE

The objective of this work is to perform the required meteorological measurement services at both actual and candidate wind turbine sites with a goal of obtaining at least 90% recovery of high quality data with meteorological sensors which have been calibrated according to National Bureau of Standards procedures.

APPROACH

The subcontractor established a calibration and maintenance schedule for all sites and an emergency maintenance plan so that repairs can be made at a site within 72 hours. The subcontractor also arranges for wind tunnel calibration of equipment, refurbishing of equipment, training the utility operators on use of equipment and receiving the data tapes from the utilities. The cassette tape data are then transferred to 9-track computer compatible tapes by the subcontractor with the data in engineering units, and incorporated into a data base by PNL. PNL prepares monthly and annual summaries of the data. Special reports at individual turbine sites are prepared for use by NASA/Lewis Research Center.

OUTPUT

Monthly 9-track data tapes, calibration reports, and site inspection reports are submitted to PNL for use in documenting monthly data reports at candidate sites. The data are distributed to participating utilities and NASA.

2.3 Site Evaluation

Project Title

Large Machine Site Evaluation

Management L.L. Wendell (509) 375-3837 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** October 1979 September 1981 ***FY 81 Funding*** FY 82 Funding $235,000 -0-
Principal Investigator D. S. Renné (509) 375-3890	**CUMULATIVE FUNDING** $510,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Continued measurements of wind characteristics at large wind turbine test sites provide an ideal data base with which to apply techniques developed through the Site Assessment and Development Techniques task, and to evaluate the turbines in the meteorological environment of the site for which they have been selected.

OBJECTIVE

This task was originally designed to assist the DOE in the selection of future sites for future large wind turbine installations. It is also to test the techniques developed in the site assessment area at actual turbine sites.

APPROACH

The meteorological towers at each turbine site will be configured to collect turbine parameters and wind characteristics information simultaneously. This has already been accomplished at three MOD-0A sites, and in 1981 the Kahuku MOD-0A and the Goodnoe Hills MOD-2 sites were instrumented in this fashion. Special high-speed data samples will be obtained from these sites periodically for use in special studies.

OUTPUT

Besides the maintenance of a turbine site data base, periodic reports relating machine performance to atmospheric conditions will be published. These reports will be designed to provide guidance on measurement activities that should be undertaken at future sites for site evaluation purposes.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title

Data Acquisition and Analysis at MOD-2 Site

Management L.L. Wendell (509) 375-3837 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** October 1979 - September 1981 ***FY 81 Funding*** FY 82 Funding $121,000 -0-
Principal Investigator D. L. Hadley (509) 375-3884	**CUMULATIVE FUNDING** $214,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

The purpose of this work is to provide the necessary hardware and software to efficiently retrieve the tremendous amount of data that is being collected at the MOD-2 site. This required the development of a sophisticated data collection system to sample all channels at up to five times/second, internally process the data and store the data for later retrieval.

OBJECTIVE

To design and install a centralized data acquisition system at Goodnoe Hills which will record all meteorological parameters from the PNL and BPA towers and selected wind turbine parameters.

APPROACH

The data system was installed and made operational in August 1981. Development of the software to store and process the data was begun.

A new 350 ft meteorological tower was installed in the spring of 1981, and began collecting data in late May 1981.

OUTPUT

The output consisted of appropriate hardware installed at Goodnoe Hills and the required software to routinely process the extremely large volumes of data collected. Monthly and seasonal summaries of the data were produced.

2.3 Site Evaluation

Project Title

Physical Modeling of Goodnoe Hills

Management L.L. Wendell (509) 375-3837 Pacific Northwest Laboratory	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, WA 99352	***Period of Performance*** October 1980 - September 1981 ***FY 81 Funding*** FY 82 Funding $31,000 -0-
Principal Investigator W. C. Cliff (509) 375-2024	**CUMULATIVE FUNDING** $31,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

One early component of the test program at the Goodnoe Hills MOD-2 site is to assess the variability of the wind throughout the region to identify other possible sites for wind turbine installations. Because of the complexity of the terrain, field test programs with sufficiently large measurement networks would be very costly to assess this variability.

OBJECTIVE

An alternative, cost-effective scheme is to physically model the area. The objective of this study is to assess the variability of flow conditions around the Goodnoe Hills test site using a scale model of the site inserted in a water flume.

APPROACH

Topographic maps were used to construct a 1:3,840 scale model of the area around the MOD-2 cluster. The model was inserted in a water flume at PNL. Visible dye tracers and hydrogen bubble tracers were ejected at several points around the model, and the resulting flow characteristics were photographed with a 16 mm camera. A laser Doppler velocimeter was also used to obtain quantitative measurements.

OUTPUT

A 16 mm sound narrated movie was made of the pertinent flow features observed at the site. Flows from southerly as well as westerly directions were simulated. The movie shows that the flow was most turbulent near the south edge of the ridge, and that for westerly conditions the flow "spills over" the ridge into the gorge. For southerly flow, significant speedup was observed as the flow approached the ridge, but no flow separation could be seen.

2.3 Site Evaluation

Project Title

Wake Studies

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** -0- FY 82 Funding $445,000
Principal Investigator D. S. Renné (509) 375-3890	**CUMULATIVE FUNDING** $445,000 *
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND A very important aspect of a cluster of large wind turbines is the spacing between the turbines. Land requirements would encourage the closest spacing possible. However, the phenomena of momentum depletion and induced turbulence in the turbine wakes may cause significant loss of efficiency or a shortening of the turbine design life if the downwind turbines are too close. In order to determine the optimum spacing in a turbine cluster, knowledge of wake structure and behavior is required.

OBJECTIVE

To conduct research which will provide the wake characterization information needed for optimum spacing in wind turbine clusters.

APPROACH During FY-1982 the Wind Characteristics Program took advantage of some unique opportunities to conduct some research on wakes behind the large wind turbines. A circular array of anemometers in a vertical plane situated two diameters from the MOD-0A at Clatyon, New Mexico, was used to measure the structure of the near wake behind a single turbine, while the wake and downwind machine interaction were measured at the cluster of three turbines at Goodnoe Hills, Washington. Smoke visualization experiments at Goodnoe Hills were also conducted to add a perspective of the wake structure not possible from wind measurements alone. Verification efforts of the momentum deficit model began with the development of a methodology suitable for coping with complications of terrain induced wind variability.

OUTPUT

Publications, in the form of reports and journal articles, from each of the individual task under this area of research.

* Including Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title

MOD-0A Single Machine Wake Tests

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** -0- FY 82 Funding $47,000
Principal Investigator J. C. Doran (509) 375-3880	**CUMULATIVE FUNDING** $47,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Land availability and use is likely to be one of the more significant constraints on the deployment of wind turbines. In order to plan wind turbine farm machine spacing, some quantitative information about wind turbine wakes and wake effects on wind turbines is required.

OBJECTIVE

To characterize the near field wake characteristics (approximately 2 rotor dia.) of the MOD-0A for comparison with the Lissaman Turbine Wake model.

APPROACH

The PNL vertical plane array (VPA) at the Clayton, NM, MOD-0A site was constructed so that prevailing wind would pass through the VPA as it approached the wind turbine. On frequent occasions the wind reverses for periods of several hours to day and flows NE to SW. This places the VPA directly downstream of the MOD-0A so that what is seen by the VPA anemometers can be averaged to obtain momentum deficit. These data are available through the existing PNL data acquisition system. In looking for wake case data, software were written that will select periods when the wind and turbine alignment are properly lined up to have the turbine wake impacting the VPA.

OUTPUT

A report entitled, Comparison of Model and Observations of the Wake of a MOD-0A Wind Turbine, PNL-4433, was published in October 1982.

2.3 Site Evaluation

Project Title

Flow Visualization Study of the MOD-2 Wind Turbine Wake

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-D-5787-A-N
Contractor Flow Industries, Inc. 21414 68th Avenue South Kent, WA 98032	***Period of Performance*** June 1982 - December 1982
	FY 81 Funding -0- FY 82 Funding $129,000
Principal Investigator H.T. Liu (506) 872-8500	**CUMULATIVE FUNDING** $129,000
WORK LOCATION Kent, WA	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, WA 99352

PROJECT SUMMARY

BACKGROUND

The spacing of wind turbines in clusters is a key issue in the cost-effective development of wind farms. The wake created by turbines result in decreased velocities and increased turbulence which adverely affect the performance of downwind turbines and decreases overall cluster efficiency. It is necessary to fully understand the characteristics of the wake from a single wind turbine to optimize the design of large arrays of turbines.

OBJECTIVE

The objective of this work is to visually document the characteristics of the wake and specific flow structures such as tip vortices behind an operating MOD-2 wind turbine.

APPROACH

Flow visualization experiments were conducted in the wake of a MOD-2 turbine at Goodnoe Hills, Washington during the summer of 1982. The experiments used several tracer techniques. Vertical smoke trails laid down by model rockets were used to obtain a vertical profile of horizonal velocity through the wake and to determine the top edge of the wake at different distances downwind of the turbine. A point source of smoke was used to inject smoke into the region immediately behind the rotor to visualize the formation and evolution of tip vortices generated by the rotor. Results were recorded on still and movie film.

OUTPUT

A report describing the results of the flow visualization experiments conducted at Goodnoe Hills, Flow Visualization Study of the MOD-2 Turbine Wake, PNL-4535, will be published in February 1983.

2.3 Site Evaluation

Project Title
Wake Structure Measurements at the MOD-2 Cluster Facility

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-D-5788-A-N
Contractor AeroVironment, Inc. 145 Vista Avenue Pasadena, CA 91107	***Period of Performance*** Jan. 1982 - December 1982
	FY 81 Funding -0- FY 82 Funding $97,000
Principal Investigator P.B.S. Lissaman (213) 449-4392	**CUMULATIVE FUNDING** $97,000
WORK LOCATION Pasadena, CA	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, WA 99352

PROJECT SUMMARY

BACKGROUND

The spacing of wind turbines in clusters is a key issue in the cost-effective development of wind farms. The wake created by turbines result in decreased velocities and increased turbulence which adversely affect the performance of down wind turbines and decrease overall cluster efficiency. It is necessary to understand the characteristics of the wake from a single turbine to optimize the design of large arrays of turbines.

OBJECTIVE

The objective of this work was to directly measure the centerline velocity deficit and turbulent intensity of the MOD-2 wake as a function of downwind distance.

APPROACH

Two 1-week field experiments were conducted in the summer of 1982 at the MOD-2 facility at Goodnoe Hills, Washington. Measurements of wind speed and direction within the wake were taken at a hub height (200') using a radiosonde suspended from a tethered balloon. Data was collected at downwind distances corresponding to 3, 5, 7, and 9 rotor diameters. Free stream wind velocities were obtained from the two tall meteorological towers located nearby.

OUTPUT

A report describing the results of wake measurement program conducted at Goodnoe Hills, Wake Structure Measurements at the MOD-2 Cluster Test Facility at Goodnoe Hills, PNL-4572, will be published in March 1983.

2.3 Site Evaluation

Project Title

Siting Techniques

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Labortory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** FY 82 Funding $44,000 $145,000
Principal Investigator D. S. Renné (509) 375-3890	**CUMULATIVE FUNDING** $189,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

In the early years of the Federal Wind Energy program, research into site screening techniques received high priority and produced siting documents for use in the preliminary stages of siting activities. In FY 1980-81 emphasis was shifted to research into individual site assessment and development. In FY 1982 research on the few remaining tasks in Siting Techniques was completed. The research on wind turbine wakes for site development purposes was shifted to a research area in its own right.

OBJECTIVE

To complete the few remaining tasks in the research on siting techniques and allow research in wind turbine wakes, wind turbulence and wind shear to be carried on in the appropriate research areas of the program.

APPROACH

The two-minute data samples of wind and turbine output from Clayton, New Mexico were statistically correlated to assess the representativeness of wind data for evaluating turbine sites. Data from several candidate sites was used to evaluate an improved flow model for estimating wind energy at a selected site. The performance of several site screening flow models, developed in the international community and tested on the same data samples, was analysed. This analysis was used to evaluate the role of numerical modeling in wind turbine siting.

OUTPUT

Reports and publications documenting the results and recommendations of the research tasks are described on subsequent pages.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title

Statistical Analysis of Wind Characteristics for Wind Energy Conversion Systems

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-B-6648-B-N
Contractor Northwestern University Evanston, IL 60201	***Period of Performance*** March 1981 - March 1982
	FY 81 Funding FY 82 Funding $44,000 $6,000
Principal Investigator Dr. Ross B. Corotis (312) 492-3453	**CUMULATIVE FUNDING** $50,000
WORK LOCATION Evanston, IL	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, WA 99352

PROJECT SUMMARY

BACKGROUND In order to make cost-effective decisions on implementing wind energy projects, proper evaluation of a site's wind characteristics must be made. However, since there is often insufficient time to fully evaluate the site, the most efficient measurement procedures must be identified to obtain maximum benefit of the site evaluation process. One method of establishing site evaluation procedures is to examine the meteorological and turbine performance data at actual turbine sites to determine what measurement strategy and data analysis schemes are more pertinent to site evaluation.

OBJECTIVE

To examine turbine performance and meteorological tower data at the Clayton, NM MOD-0A site to determine a wind characteristics measurement strategy that is most pertinent to estimating actual machine performance at the site.

APPROACH

Statistical analysis of data samples once every two minutes from the DOE meteorological tower and the MOD-0A at the Clayton, NM sites were made. Using cross-correlatic and autocorrelation analysis, various hypotheses with respect to sampling rates and sensor heights were tested. A scheme for simulating wind speed time series for site evaluation was also developed.

OUTPUT

A paper entitled "Assessing the Representativeness of Wind Data for Wind Turbine Site Evaluation" was published in the Proceedings of the Large Horizontal Axis Wind Turbine Conference, SERI/CP-635-1273, in 1982 and a report entitled Simulation of Wind Speed Time Series for Wind Energy Conversion Analysis, PNL-4349, was published in September 1982.

2.3 Site Evaluation

Project Title

Use of Improved Windflow Model to Estimate Wind Characteristics at New Candidate Sites

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-D-5789-A-E
Contractor SRI-International 333 Ravenswood Avenue Menlo Park, CA 94025	***Period of Performance*** May 1982 to November 1982 ***FY 81 Funding*** -0- FY 82 Funding $58,000
Principal Investigator R. M. Endlich (415) 326-6200	**CUMULATIVE FUNDING** $58,000
WORK LOCATION Menlo Park, CA	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, WA 99352

PROJECT SUMMARY

BACKGROUND Under previous contracts, a numerical model has been developed to estimate wind characteristics at candidate wind turbine sites utilizing nearby National Weather Service data and incorporating the effects of terrain between the NWS stations and the candidate site. This model has shown to be a promising technique to obtain some preliminary site evaluation data prior to the collection of actual onsite measurements. During the course of the earlier work, certain improvements to the model were identified that would improve its accuracy and efficiency.

OBJECTIVE

To improve the windflow model developed under earlier contracts in the wind program, and to apply the model to four new sites.

APPROACH

The model was revised in two basic ways:

1. Improving the method for using the geostrophic wind in making the initial wind analyses.
2. Formulating a more appropriate method for calculating nondivergent flow.

Computer runs will be made with the new formulation and compared with earlier results.

OUTPUT

A report entitled An Improved Diagnostic Model for Estimating Wind Energy, PNL-4526, will be published in March 1983. The report describes the pertinent features of the modified computer code, the results of the comparisons with the new and old versions as applied to San Gorgonio Pass, Block Island, and Clayton, and the results of application of the new model to Romero Overlook, CA; Goodnoe, Hills, WA; Stratton Mountain, VT; and Meade, KS.

2.3 Site Evaluation

Project Title

Flow Model Evaluation for Sparse Data Areas

Management Pacific Northwest Laboratory L.L. Wendell (509)375-3870	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, Washington 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** -0- FY 82 Funding $38,000
Principal Investigator W.T. Pennell (509 375-3814	**CUMULATIVE FUNDING** $38,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

In 1978 the United States and several other countries entered into an agreement through the International Energy Agency (IEA) to evaluate the capabilities of numerical models to assist in wind turbine siting. This report summarizes the results of this project.

OBJECTIVE

To summarize and report the results of the International Energy Agency (IEA) modeling comparison study.

APPROACH

The abilities of five numerical models to simulate flow over various types of terrain have been assessed by comparing simulated with observed surface windfields over various types of terrain. The models ranged from simple, mass-consistent, objective analysis schemes to highly complex primitive equation models. The terrain investigated ranged from a simple, flat island to a complex mountainous region of Nevada. A procedure for comparing model "predictions" with observed windfields was developed and each modeler ran his model for a common set of test cases. The modelers completed their work in FY 1982. PNL summarized these reports and provided an assessment of the role of numerical modeling in wind turbine siting. The individual reports from the modelers will be appendices to the PNL report to the IEA.

OUTPUT

A report to the IEA entitled, An Evaluation of Wind Field Models in Wind Turbine Siting, describes the models tested, the methods of comparison, the results of this comparison, and the implications of these results to wind turbine siting.

2.3 Site Evaluation

Project Title

Forecasting Research for Wind Turbine Operations

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** FY 82 Funding $252,000 $683,000
Principal Investigator A. H. Miller (509) 375-3886	**CUMULATIVE FUNDING** $935,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

The effective operation of wind turbines in a power network requires knowledge of and methods for coping with wind variability in time and space. The time variability ranges from minutes to days. The space variability includes the vertical direction over the depth of the rotor disc and the horizontal direction over the dimensions of a wind turbine clusters and the distance between clusters.

OBJECTIVE

To conduct research in the areas of wind turbine control strategy model testing, wind forecasting for wind energy utilization, short record extrapolation and wind correlation effects on wind turbine array performance, with the goal of providing results which can help to increase energy capture efficiency.

APPROACH

Specific approaches to each of the tasks in this research area are included on the sheets for those tasks. One of the major activities in FY 1982 included the verification of the operations model for the MOD-0A with wind on turbine data from Clayton, New Mexico. Another was the wind forecast verification activities having operational forecasters apply the methods developed in FY 1981.

OUTPUT

The results of this research area are published in reports or in journal articles which are referenced on the individual project sheets.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title
Large Wind Turbine Operations Performance Modeling

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3837	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, Washington 99352	***Period of Performance*** October 1980 - Continuing ***FY 81 Funding*** FY 82 Funding $57,000 $132,000
Principal Investigator A. H. Miller	**CUMULATIVE FUNDING** $189,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Improved models are needed for predicting energy production from large wind turbines connected to electric utilities. Quasi-dynamic computer models of current and future large wind turbines are a tool which will assist planners and decision makers in the process of siting LWECS, estimating the LWECS operating characteristics in various wind regimes, estimating the likely energy capture and defining a useful measurement program for future candidate sites.

OBJECTIVE

To develop, optimize, test and document numerical, quasi-dynamic wind turbine models incorporating their operating strategy; to determine using these models, what typical and/or site specific wind characteristics affect the operation of LWECS and to attempt to ascertain the validity of the modeling approach to the optimization of LWECS.

APPROACH

The currently existing large turbine computer models are undergoing the process of validation using wind and turbine input data from appropriate installation sites. In the process of validation it has been shown that sime potential wind data pre-processing would reduce the short term variance in the model output as opposed to the actual turbine. By manipulating data especially collected at high rates and high vertical resolution, an optimum input data descriptor would result. With the validated models computer simulation at diverse sites can be accomplished for extended periods for energy capture estimates and turbine optimization.

OUTPUT

This project will produce documented, verified, transportable computer models of current wind turbines (MOD-0A, MOD-2) and reports on their development and testing. These reports will include the effects of wind characteristics on the operations of LWECS and the effects of modifying the operating strategy on a turbine's overall operation and energy capture. A report will be prepared in FY 83.

2.3 Site Evaluation

Project Title

Forecast Integration Into Utility Operation

Management L.L. Wendell (509) 375-3837 Pacific Northwest Laboratory	**CONTRACT NO.** B-93474-A-1
Contractor JBF Scientific Corp. 2 Jewell Drive Wilmington, MA 01887	***Period of Performance*** March 1980 - October 1981
	FY 81 Funding -0- FY 82 Funding -0-
Principal Investigator M. K. Goldenblatt (617) 657-4170	**CUMULATIVE FUNDING** $65,000
WORK LOCATION Wilmington, Massachusetts	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

In late FY-79, a computer model was developed at PNL which simulates the time dependent MOD-2 power output using 2-minute wind data from candidate sites and the operating strategy specified for the turbine. This model and the results from a wind forecasting task provided the basic information for this study.

OBJECTIVE

To examine utility operations to determine the impact on WECS value due to using higher wind sampling rates, simulation of the WECS operating strategy, and to test the sensitivity of WECS value to wind forecasting accuracy.

APPROACH

Data from a DOE candidate site was the basis of the wind power analysis and data on the loads and utility generation mix, specific operating procedures and dispatch schedules and unit commitment for a utility serving the area were run through a utility cost production model for the period of 1 year assuming 0 and 10% penetration of WECS with the wind input having four different sampling characteristics.

OUTPUT

A report entitled, Analysis of the Effects of Integrating Wind Turbines into a Conventional Utility: A Case Study, PNL-3962, was published in August 1982. The final report documents the economic value of WECS in a real utility situation, the value and required accuracy of wind forecasting and the capacity credit differences evidenced by the four different sampling strategies.

2.3 Site Evaluation

Project Title

Characterization of Site Winds for WECS Operations

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-82873-A-U/B-B6618-A-U
Contractor Freese-Notis Weather 1453 Northeast 66 DesMoines, IA 50313 Murray and Trettell Inc. 414 W. Frontage Road Northfield, IL 60093	***Period of Performance*** February 1981 to April 1982 ***FY 81 Funding*** FY 82 Funding $145,000 $24,000
Principal Investigator Charles Notis (515) 289-1314 Dennis Trettell (312) 446-7800	**CUMULATIVE FUNDING** $169,000
WORK LOCATION DesMoines, IA/Northfield, IL	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

Recent investigations have shown that if significant penetrations of wind energy into utility systems are to be achieved, accurate reliable wind forecasts will be required. Traditional wind forecasts appear unsuited for this purpose.

OBJECTIVE

To complete the development of a method of forecasting wind for wind energy applications.

APPROACH

Analysis of one year of hourly average winds was performed for six selected DOE sites. Weather elements and patterns were correlated with site specific wind events. Tabulation of these data led to formulation of guidelines both for learning to forecast winds for wind energy applcations in general and for forecasting specifically for the six sites examined.

OUTPUT

A report was drafted describing the interaction of various meteorological phenomena and site specific winds as well as describing how to use this information to develop wind forecasts for wind energy applications. The final report, Learning to Forecast Wind at Remote Sites for Wind Energy Application, PNL-4318, will be published in January 1983.

2.3 Site Evaluation

Project Title

Verify Technique for Wind Forecasting for 12 to 24 Hours

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** FY 82 Funding $50,000 $160,000
Principal Investigator H. L. Wegley (509) 375-3891	**CUMULATIVE FUNDING** $210,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Recent investigations have shown that if significant penetrations of wind energy into utility power generation are to be achieved, accurate reliable wind forecasts are needed. Present wind forecasts appear inadequate, but a new approach to wind forecasting for wind energy applications promises improved accuracy and reliability and needs independent verification. An FY 81/82 task involved a study of large-scale weather and its site-specific effects on the wind.

OBJECTIVE

To complete the development and testing of a useful method of forecasting wind for wind energy applications.

APPROACH

Wind forecasting guidelines based upon the FY 81/82 analysis were tested by having a group of independent forecasters use the guidelines to produce wind forecasts for a period of six months. To ensure timely feedback to the forecasters, the forecasting sites were selected from those DOE candidate sites having telephone dial-up systems.

OUTPUT

A final report, Test Application of a Semi-Objective Approach to Wind Forecasting, PNL-4403, will be published in February 1983.

2.3 Site Evaluation

Project Title

Weather Pattern Climatology for the Great Plains

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982
	FY 81 Funding -0- / FY 82 Funding $91,000
Principal Investigator W. R. Barchet (509) 375-3876	**CUMULATIVE FUNDING** $91,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Previous research has shown that the wind climatology is related to the climatology of weather patterns that drive the wind. This work was done in an analysis of the coastal wind resource. A similar variety of weather patterns affects the high wind resource area of the Great Plains. A climatology of weather pattern type would aid the understanding of this wind resource area.

OBJECTIVE

Produce a climatology of Great Plains weather pattern types and relate these to the climatology of the wind regime.

APPROACH

The distribution of the frequency of occurrance of weather pattern type over the Great Plains was determined from a time series of weather pattern type at 62 Great Plains stations. The relationship between weather pattern and wind regime was determined by stratifying the wind regime by pattern type.

OUTPUT

A report, A Weather Pattern Climatology of the Great Plains and the Related Wind Regime, PNL-4330, presented maps of the distribution of weather pattern types over the Great Plains and graphs showing the relation between the wind regime and weather pattern type.

2.3 Site Evaluation

Project Title

Weather Pattern Climatology for the Continental United States

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-D-5793-A-X
Contractor San Jose State University Foundation San Jose, CA 195192	***Period of Performance*** May 1982 - September 82
	FY 81 Funding -0- FY 82 Funding $47,721
Principal Investigator Dr. P. F. Lester (408) 277-3635	**CUMULATIVE FUNDING** $47,721
WORK LOCATION San Jose, California	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, Washington

PROJECT SUMMARY

BACKGROUND

Earlier work on weather pattern climatology of the coastal zone and of the Great Plains had shown the usefulness of a climatology of weather pattern type for evaluating the meteorological mechanisms during the observed wind resource and for comparing the meteorological conditions during a particular observation period to the long term mean.

OBJECTIVE

The objective is to produce a time series of weather pattern type for the conterminous 48 states of the United States.

APPROACH

Weather pattern types were defined with respect to the distribution of barometric pressure about an extra tropical cyclonic storm. A methodology to consistently classify weather patterns was developed. Time series of the weather pattern were determined for 120 points uniformly spaced across the USA. The pattern of weather pattern types were carefully checked for temporal and spacial continuity.

OUTPUT

A report describing the methodology for typing weather patterns and a data tape containing the time series of weather patterns at the 120 points for the period 1/1/69 through 12/31/78 will be prepared in FY-83.

2.3 Site Evaluation

Project Title

Development of Vertical Adjustment Techniques

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** FY 82 Funding -0- $78,000
Principal Investigator J. C. Doran (509) 375-3880	**CUMULATIVE FUNDING** $78,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND In order to make a meaningful prediction of the possible energy production by a wind turbine, it is necessary to adjust available data to the hub height of the machine. At present, various power laws are used for the adjustment, but their utility can be severely limited by terrain and stability factors. In addition, their behavior is a function of height, and this combination of effects is frequently ignored. An explicit treatment of these items can significantly improve the use of power laws for extropolation of low-level winds to hub heights.

OBJECTIVE

To develop and test techniques to obtain wind speed at one height from wind speeds measured at a lower height.

APPROACH

The wind shear climatology and power law studies will be based on tower data from candidate and turbine sites, and also from tall towers such as the KYTV tower near Oklahoma City, OK. Wind shears will be analyzed as a function of wind speed, stability, terrain type and height above the surface. The utility of power laws for speed extrapolation was investigated and evaluated.

OUTPUT

A report entitled Vertical Extrapolation of Wind Speed, PNL-4361, was published in September 1982.

2.3 Site Evaluation

Project Title
Wind Turbine Array Performance Simulation

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3879	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** -0- FY 82 Funding $113,000
Principal Investigator D. C. Powell (509) 375-3888	**CUMULATIVE FUNDING** $113,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND Until recently the wind characteristics effects on wind turbines have been applied primarily to single machines. The typical end user may have several clusters of wind turbines organized into an array which is spread over distances of 10 to 50 miles. Wind characteristics exist that can cause turbines within a cluster or between clusters in an array to experience significant differences in wind speed, direction and turbulence levels over short time intervals. These effects may be significantly related to the dynamic stability of the grid, the spinning reserve requirements and attendant economic penalty.

OBJECTIVE
To complete an analysis of existing sets of time series wind data from several networks of wind measurement stations, over areas on the order of 10 diameters to 50 miles square, and to determine the effects of this scale of wind variability on the operation of a network of wind turbines or clusters of wind turbines.

APPROACH
The research addressed primarily the more routine turbulent variability in the wind over an area in which wind turbines are to be installed. The two scales of concern are: 1) the spacing between turbines in a cluster, and 2) the spacing between the clusters in an array. The data from the BPA and PNL towers at the Goodnoe Hills MOD-2 site were used to study the nature of a wind variability on the scale of turbine separation. Wind data from a dense network of anemometers were used to analyze and model the nature of wind variability on the scale turbine clusters spacing throughout the array.

OUTPUT
The results of this task will be a report in early FY 1983 on wind variability statistics that can be applied to wind data to ascertain the effects of spatial variability on turbine output and electrical grid dynamics.

2.3 Site Evaluation

Project Title

Microscale Turbulence and Wind Turbine Loads

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RL0-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** $310,000 FY 82 Funding $422,000
Principal Investigator J. R. Connell (509) 385-3879	**CUMULATIVE FUNDING** $732,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

Preliminary analyses have indicated that the fluctuating behavior of blade bending moment and turbine power output from the MOD-0A at Clayton, New Mexico showed a striking resemblance to the turbulent fluctuations of rotationally sampled winds from a vertical plane array of anemometers. This finding led to an accelerated effort to acquire a high quality, high resolution set of simultaneous measurements of turbine parameters and wind data from the Clayton site. This data could serve as a basis for the verification of newly developed models for providing information needed in dynamic stress load analyses.

OBJECTIVE

To acquire simultaneous measurements of winds on the vertical plane array of anemometers and turbine blade bending and output response until a wide range of turbulent conditions have been adequately sampled. To pursue theoretical development and modeling of the rotational sampling concept for application to wind turbine design.

APPROACH

The wind turbine parameters were patched directly into the PNL data acquisition system for simultaneous recording with the wind data. Data was collected when the turbine was operating and the wind direction was from the array to the turbines, or from the turbines to the array for wake analyses. Spectral analysis of turbine parameter data were correlated with those from the rotationally sampled winds. This information was used in the modification and verification of models of turbine response to wind fluctuations Other methods of sampling were also explored.

OUTPUT

The results of this research area are published in reports or in journal articles which are referenced on the individual project sheets.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title

Flow Through a Vertical Plane Array

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P.O. Box 999 Richland, Washington 99352	***Period of Performance*** October 1980 - Continuing ***FY 81 Funding*** FY 82 Funding $259,000 $238,000
Principal Investigator J. R. Connell (509) 375-3879	**CUMULATIVE FUNDING** $497,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

The importance of characterizing wind around and across the disk of rotation of a wind turbine has been demonstrated. However, the requisite measurement capability had not been installed at a wind turbine site. Of the DOE wind turbine sites only the Clayton site had a research instrumented, large turbine and a suitable location on which to place an upwind vertical plane array.

OBJECTIVE

To measure the space and time variations of the wind in a cross-wind disk in front of the MOD-0A wind turbine at Clayton, New Mexico. To provide characteristics in the rotational frame of reference in this high plains, high wind, nocturnal wind shear maximum location. To relate the wind characteristics to wind turbine response.

APPROACH

Seven meteorological towers in a vertical plane orthogonal to the prevailing wind at Clayton, New Mexico were erected several turbine diameters upwind of the MOD-0A turbine. Wind instruments were placed on the towers with U, V, W anemometers equally spaced at 12 points around a 125 ft diameter circle centered on hub height. Data is being recorded at turbulence rates and analysis in the rotating frame using spectral, gust and correlation methods is being undertaken to relate to Eulerian (fixed point) wind statistics. Further these analyses will be related to wind turbine response.

OUTPUT

Publications: The Spectrum of Wind Speed Flunctuations Encountered by a Rotating Blade of a Wind Turbine System, J.R. Connell, Solar Energy, Vol. 29, No 5, pp 363-375, 1982. The Wake of the MOD-0A Wind Turbine at Two Rotor Diameters Downwind on December 3, 1982, PNL-4210, November 1982. Wind Characteristics at a Vertical Plane Array of Anemometers That Correlate Well With MOD-0A Wind Turbine Responses, report to be published in March 1983.

2.3 Site Evaluation

Project Title
Engineering, Technical and Data Processing Services in Support of the PNL V.P.A. Studies at Clayton, New Mexico

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-C-3022-A-N
Contractor New Mexico Engineering Research Institute University of New Mexico Campus P.O. Box 25 Albuquerque, NM 87131	***Period of Performance*** May 1981 to December 1982 ***FY 81 Funding*** $51,000 FY 82 Funding $46,000
Principal Investigator G. Frey (505) 846-0779	**CUMULATIVE FUNDING** $97,000
WORK LOCATION Albuquerque and Clayton, New Mexico	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, WA 99352

PROJECT SUMMARY

BACKGROUND

PNL performs research at Clayton, New Mexico correlating the measured wind at a vertical plane array of anemometers with the measured response of the MOD-0A wind turbine. Because of the magnitude of the measurements effort and the large distance of PNL from the Clayton, New Mexico site, local field support is required for quickness of response and economics.

OBJECTIVE

To be able to make continuous measurements (to change data tapes, change the data taking mode to suit current wind conditions, repair and calibrate systems, disconnect electrical systems during lightning storms) of wind and turbine parameters in an economical way. Add capability to measure vertical profiles of temperature.

APPROACH

NMERI personnel provide routine and frequently required services at Clayton from Albuquerque for more technical requirements where 2 to 5 hour delays in response are acceptable, or where several weeks of technical effort at Clatyon are required, or several people are required. For fast 1/2 hour response or for continuous support or single person support a part-time employee of the University of New Mexico who lives in Clayton is provided by New Mexico Engineering Research Institute .

OUTPUT

Services: System condition monitoring, protection, repair and testing and upgrading; routine measurements and shipping of data tapes to PNL; some engineering analysis of the measurement systems; some construction of components of the measurement system. A four level aspirated temperature measuring system that attaches to 4 met. tower elevators was tested, used briefly at Clayton, New Mexico prior to program shut-down.

2.3 Site Evaluation

Project Title

Response of the MOD-0A Wind Turbine Rotor to Turbulent Atmospheric Wind

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AM06-76RL02227
Contractor Oregon State University Corvallis, OR 97331	***Period of Performance*** April 1982 - December 1982
	FY 81 Funding -0- FY 82 Funding $25,000
Principal Investigator R. W. Thresher (503) 754-2535	**CUMULATIVE FUNDING** $25,000
WORK LOCATION Corvallis, Oregon	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

The Oregon State Univ. model developed in the previous year did not include enough high order terms in the wind input. Further it was not tested against a wind turbine nor was model output such that the objective, of finding what wind characteristics were important, could be achieved.

OBJECTIVE

Refine the model and test it against PNL analysis of wind and MOD-0A wind turbine response at Clayton, New Mexico.

APPROACH

To include higher order terms in the mathematical expansion of the wind field. Correct previous programming errors. Run the revised Oregon State University model to complete MOD-0A rotor responses measured for three specific wind conditions at Clayton. Make comparisons in the Spectral Domain.

OUTPUT

The computations have been made using the Oregon State Univ. model. Comparisons have begun and a full report is expected in January 1983 including some preliminary material received in late December 1982. The results appear still to underestimate wind effects in the frequency range greater than that of rotor RPM.

2.3 Site Evaluation

Project Title

Modeling Wind Speed Profiles in Complex Terrain

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-D-5794-A-N
Contractor University of Massachusetts The Applied Technology Center School of Engineering Amherst, MA 01003	***Period of Performance*** June 1982 to December 1982 ***FY 81 Funding*** FY 82 Funding -0- $30,000
Principal Investigator Dr. Robert Kirchhoff (413) 545-0949 Dr. Frank Kaminsky (413) 545-2851	**CUMULATIVE FUNDING** $30,000
WORK LOCATION Amherst, MA	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, WA 99352

PROJECT SUMMARY

BACKGROUND

Wind speed vertical profiles in complex terrain, where wind turbines are often placed or desired are not well described by current models. The University of Massachusetts has an ongoing program of wind measurements at complex sites that would add to the existing knowledge.

OBJECTIVE

To construct a model of vertical variation of wind speed at several selected sites in New England.

APPROACH

To use Tala-Kite wind measurements and weather maps to stratify the wind profiles according to synoptic weather conditions on a statistical basis.

OUTPUT

A report entitled Empirical Modeling of Wind Speed Profiles in Complex Terrain, DOE/ET/10374-82/1 will be published in March 1983.

2.3 Site Evaluation

Project Title

Measurement of Turbulent Wind Velocity Using Rotating Boom Apparatus

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** B-D-5792-A-X
Contractor Colorado State Univ. Engineering Research Center Fort Collins, CO 80523	***Period of Performance*** May 1982 - November 1982
	FY 81 Funding -0- FY 82 Funding $70,000
Principal Investigator Prof. Virgil Sandborn (303) 491-8551	**CUMULATIVE FUNDING** $70,000
WORK LOCATION Fort Collins, CO	**CONTRACTING OFFICE** Pacific Northwest Laboratory Richland, WA 99352

PROJECT SUMMARY

BACKGROUND

There has been a serious deficiency in measurement of turbulence wind as observed from points on wind turbine rotor blades. The most direct method is to measure with anemometers attached to rotor blades. No such apparatus existed.

OBJECTIVE

Construct, test and demonstrate hot film anemometer systems for measuring turbulence wind from a rotating boom apparatus with variable geometry and rotation capability.

APPROACH

Use commercial hot film anemometers to build 3-dimensional anemometers that attach to rotating booms. Include a digital, computer-based, magnetic tape data acquisition system with data quality slip rings to transmit from rotor to data recording system. Include a variable height tower and a variable axis direction rotor drive to permit generalized research on wind effects.

OUTPUT

The apparatus has been completed and most tests have been performed. The contractor has not been able to retain adequate help with the data acquisition system. Thus fewer experiements were performed than anticipated. The complete apparatus is to be shipped to PNL in December 1982 for continued use. A final report will be included from CSU.

2.3 Site Evaluation

Project Title

Wind Shear Climatology from Tall Towers

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - Continuing ***FY 81 Funding*** FY 82 Funding -0- $110,000
Principal Investigator D. L. Elliott (509) 375-3881	**CUMULATIVE FUNDING** $110,000
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

A potential problem in applying the average profile concept to a large rotating turbine blade in design or operational considerations is that the blade does not encounter an average wind profile. Rather, the blade experiences the wind shear that occurs during the two or four seconds that it takes to comple one rotation. In order to estimate the amount of extreme shear a turbine will experience and the subsequent effects on fatigue life and power quality, it is extremely important to obtain and analyze appropriate wind data.

OBJECTIVE

To analyze wind shear environments relevant to the fatigue life, operations and energy capture of a large wind turbine.

APPROACH

An analysis scheme was developed to establish a climatology of wind shear profiles derived from 10-s sampled winds and hourly average winds measured over a one-year period at several levels on a tall tower. Because of the sensitivity of the forcing function variability to profile shape, the analyses performed and presented are in the form of joint frequency distributions of velocity differences of the top-to-hub versus the hub-to-bottom portion of disks of rotation for the three turbine configurations.

OUTPUT

A report entitled Wind Shear Climatology for Large Wind Turbine Generators, PNL-4308, was published in October 1982.

2.3 Site Evaluation

Project Title

Wind Resource Data Base and Information System

Management Pacific Northwest Laboratory L. L. Wendell (509) 375-3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1980 - September 1982 ***FY 81 Funding*** FY 82 Funding $139,000 $110,000
Principal Investigator W. R. Barchet (509) 375-3876	**CUMULATIVE FUNDING** $249,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND

The production of the 12 regional wind energy resource atlases for the U.S.A. resulted in the collection and processing of a large amount of wind data. Data for over 600 stations in the National Climatic Center TD1440 tape set were analyzed for wind resource assessment. The statistics resulting from the analyses and the U.S.A. resource assessment analysis constitute a major data resource for wind energy purposes that needs to be publicly available.

OBJECTIVE

The objective is to organize the analysis of wind resource and assessment data into easily accessible and computer compatible data bases and to transfer these data bases to a host who can provide public access to the data.

APPROACH

Two major data sets are involved: the TD1440 statistical analysis and the wind resource data grid. Processing of the TD1440 analyses involves extracting specific data sets from the large volume of tabulated statistics. Processing of the resource assessment data involves merging the gridded resource assessment maps for every state into a single national data set. The data sets are so organized that data retrieval programs can access and extract well defined subsets of the data.

OUTPUT

Products of this activity are computer data files and programs to access the data. Four data sets and retrieval programs deal with the TD1440 statistical analysis: means and frequency distributions; inter-intra-annual means; climatic means and events; and speed and direction persistence. A wind resource data grid on 1/4° latitude by 1/3° longitude centers is available for the conterminous U.S.A. These data sets and the computer programs to access these data were transfered to the National Climatic Center, Asheville, NC, which will make these data publicly available.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

2.3 Site Evaluation

Project Title

Measurement Programs at MOD-0A, MOD-2, and Candidate Sites

Management Pacific Northwest Laboratory L. L. Wendell (509) 3870	**CONTRACT NO.** DE-AC06-76RLO-1830
Contractor Pacific Northwest Laboratory P. O. Box 999 Richland, WA 99352	***Period of Performance*** October 1981 - September 1982 ***FY 81 Funding*** -0- FY 82 Funding $455,000
Principal Investigator D. S. Renné (509) 375-3890	**CUMULATIVE FUNDING** $455,000*
WORK LOCATION Richland, Washington	**CONTRACTING OFFICE** DOE Richland Operations Office Richland, Washington

PROJECT SUMMARY

BACKGROUND Continued measurements of wind characteristics at turbine sites are important for research activities on subjects such as machine performance evaluation and site characterization. Measurements at the candidate sites installed in FY 1981 were scheduled to continue until each site had one year of documentation. However, in many cases the host utility was interested in continuing the measurement program at their own expense. By transferring the equipment to the utilities, they could benefit by obtaining "hands-on" site evaluation experience for their own future wind energy activities.

OBJECTIVE

To operate and maintain meteorological measurement and data logging systems at DOE turbine sites (for MOD-0A sites and the MOD-2 cluster site), and also to close out the Candidate Site Program and to transfer equipment and measurement activities to interested utilities at Candidate Sites.

APPROACH

PNL provided calibration, maintenance, and data reduction activities at four MOD-0A and MOD-2 sites, as well as at San Gorgonio Pass, in support of a private wind turbine testing program. At the remaining candidate sites, PNL will work closely with those utilities interested in continuing the measurements at their own expense by providing guidance in the maintenance and calibration of the equipment by processing the cassette data tapes.

OUTPUT

A series of reports have been published: Candidate Wind Turbine Generator Site Annual Data Summary for January 1981 Through December 1981, PNL-4283, September 1982; Candidate Wind Turbine Generator Site Summarized Meteorological Data for the Period December 1976 - December 1981, PNL-4407, September 1982; Meteorological Field Measurements at Potential and Actual Wind Turbine Sites, PNL-4431, September 1982.

* Includes Subcontractor's costs and PNL subtask costs shown on subsequent pages.

3.1 Small Systems Technology

Project Title
Dynamic Stall Completion

Management Rockwell International D. C. Shepherd (303) 497-7167	CONTRACT NO. DE-AC04-76DP03533
Contractor Aerospace Systems, Inc. 121 Middlesex Turnpike Burlington, MA 01803	*Period of Performance* October 1, 1980 - September 30, 1982
	FY 81 Funding $58,000 — *FY 82 Funding* $-0-
Principal Investigator John Zvara (617) 272-7517	CUMULATIVE FUNDING $245,900
WORK LOCATION Contractor's Facility	CONTRACTING OFFICE Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND
Dynamic stall is the phenomenon that occurs when an airfoil oscillating in pitch develops a lift coefficient significantly greater than the static stall value. Little is known as to the positive or negative impacts that dynamic stall may have on wind turbine performance and reliability.

OBJECTIVE
- To provide the SWECS designer with an analytical method to determine the influence of dynamic stall on vertical and horizontal-axis wind turbine performance and blade loading.

APPROACH
The contracted effort consists of two phases. In Phase I, a data base of both theoretical and experimental information was compiled and used to develop a dynamic stall theory suitable for the SWECS designer. In Phase II, an assessment of the influence of dynamic stall on representative horizontal and vertical-axis SWECS using the developed theory was made.

OUTPUT
A technical report will be published in FY 1983 that documents the theory of dynamic stall from experimental and analytical viewpoints and provides an estimate of the significance of the dynamic stall phenomenon on SWECS.

3.1 Small Systems Technology

Project Title

Rotor/Load Matching Completion

Management Rockwell International D.C. Shepherd (303) 497-7167	**CONTRACT NO.** PF-98655-N
Contractor New Alchemy Institute P.O. Box 432 Woods Hole, Massachusetts 02543	***Period of Performance*** October 1, 1980 to September 30, 1982 ***FY 81 Funding*** -0- FY 82 Funding -0-
Principal Investigator Joe Seale (617) 563-2655	**CUMULATIVE FUNDING** $60,600
WORK LOCATION Contractor's Facility	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

The SWECS industry has often experienced cases of rotor-load mismatch. The result is generally failure of the rotor to reach its optimum tip speed ratio (and hence its optimum efficiency). No consistent methodology has been developed for use by the SWECS designer in matching the rotor torque/rpm output characteristics with the torque/rpm input characteristics of an energy conversion unit.

OBJECTIVE

To develop a low cost methodology for SWECS designer's to optimally match rotor output characteristics with a variety of different load torque requirements.

APPROACH

A graphical method of predicting wind system output using analytical expressions for total wind energy available, the rotor torque characteristics, and the load torque characteristics was developed and verified by comparing the predictions against measured outputs for a selected SWECS. Further verification and refinement work was performed during FY 1982.

OUTPUT

A computer program has been developed to predict system performance based on specific wind regimes, rotor characteristics, and governing methods. A technical report will be published in FY 1983 to document a simplified designing methodology for matching specific SWECS rotors to specific loads.

3.1 Small Systems Technology

Project Title

Performance Model Evaluation Completion Comparison Study

Management Rockwell International D. C. Shepherd (303) 497-7167	**CONTRACT NO.** 1. PFN-13318-W, 2. PFN-13470-W 3. PFN-13317-W, 4. PFN-13570-W
Contractor 1. Oregon State University 2. AeroVironment, Inc. 3. Aerospace Systems, Inc. 4. United Tech. Research Center	***Period of Performance*** October 1, 1980 - September 30, 1982
	FY 81 Funding $37,000 ***FY 82 Funding*** -0-
Principal Investigator 1	**CUMULATIVE FUNDING** $317,900
WORK LOCATION Contractor's Facility	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

SWECS designers depend heavily on theoretical performance and load predicting models for sizing their machines. Though these models have been compared to a limited amount of SWECS data, a thorough and systematic validation of the applicability to SWECS has never been undertaken.

OBJECTIVE

- To determine the accuracies and limitations of a variety of different rotor performance models and provide the SWECS designer with unbiased comparisons among the models.

APPROACH

Four contractors have been tasked to make performance predictions using their own nonproprietary and fundamentally different performance models. The predicted performance will then be compared with measured performance data taken at RF. Each contractor is to conduct a comparative analysis of the actual and predicted performance and provide an assessment of the difference.

OUTPUT

A technical report will be published in FY 1983 to document each of the performance models used and describe the limitations and shortcomings of each model.

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[1] OSU - Robert E. Wilson (503) 754-2218
AI - Burt Hibbs (213) 449-4392
ASI - John Zvara (617) 272-7517
UTRC - Al Egolf (203) 727-7188

3.1 Small Systems Technology

Project Title

Rotor Wake Measurements

Management Rockwell International D. C. Shepherd (303) 497-7167	CONTRACT NO. DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 - September 30, 1981
	FY 81 Funding $37,000 ***FY 82 Funding*** -0-
Principal Investigator A. C. Hansen (303) 497-7153	CUMULATIVE FUNDING $99,600
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	CONTRACTING OFFICE Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Understanding the profile and variability of a wind turbine wake is important for various reasons. The design of optimum and reliable rotors depends on the availability of valid load prediction models which in turn are extremly sensitive to how the wake is characterized. Verified analytical models are needed for designing optimized wind turbine arrays for wind farm applications.

OBJECTIVE

- To quantitatively measure the nature and extent of the wake around a horizontal-axis SWECS and to provide data necessary to validate rotor wake models.

APPROACH

Fast response, three-component velocity measurements were made using acoustic anemometers with emphasis placed on measuring the wake persistence and vortex location. The measurements were made by RF personnel during the SWECS controlled velocity tests at the DOT Test Center. Work on this project was terminated in early FY 1982.

OUTPUT

A technical memorandum, Early Results from the SWECS Rotor Wake Measurement Project, was distributed to industry in FY 1983. The report described the experimental methods used and documented the test data.

3.1 Small Systems Technology

Project Title

SWECS/Heat Churn System Integration Evaluation

Management Rockwell International A. R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 - September 30, 1981
	FY 81 Funding $215,000 ***FY 82 Funding*** -0-
Principal Investigator M. P. Schroeder (303) 497-7166	**CUMULATIVE FUNDING** $215,000
WORK LOCATION Rocky Flats Wind Systems Test Center	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Heating by mechanical agitation (such as a heat churn) was identified during the RF technology assessment (February 1980) as part of an advanced concept which promises a high potential for lowering SWECS cost of energy.

OBJECTIVE

To identify design specifications for an advanced concept SWECS development.

APPROACH

An assessment of the state-of-the-art in heat churn/SWECS technology was conducted to provide overall direction/scoping for this project. In-house system analyses and trade studies were conducted to determine detailed project objectives and approaches.

OUTPUT

A report (An Assessment of SWECS/Mechanical Heating Systems, RFP-3261), was written which assesses the state-of-the-art for mechanical heating devices and SWECS.

3.1 Small Systems Technology

Project Title

Tower Dynamics

Management Rockwell International M. P. Schroeder (303) 497-7166	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 to September 30, 1982
	FY 81 Funding FY 82 Funding $34,000 -0-
Principal Investigator A. D. Wright (303) 497-7138	**CUMULATIVE FUNDING** $72,800
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Proper matching of rotors and towers to avoid vibration and the associated systems reliability problems requires accurate prediction of tower vibration modes and frequencies. At present, there is a variety of structural dynamic models that cover a wide range of complexity, cost, and applications. An examination of these models is needed to determine which models are most appropriate and useful to a SWECS designer.

OBJECTIVE

To identify structural dynamic analyses appropriate for modeling wind turbine towers and to verify their accuracy by comparison with test data.

APPROACH

A variety of analysis codes which cover a wide range of sophistication were examined. Selected programs were entered and run on the Rocky Flats computer system. Emphasis was placed upon identifying those models which are simple to use, have low operational costs, and give adequate results. Comparisons were made with actual test data obtained from tower vibration tests conducted at Rocky Flats. Truss, pole, guyed, and free standing towers were evaluated. In FY 1982, work in this technical discipline was distributed among other research projects.

OUTPUT

A final report entitled Tower Dynamics Analytical Models: Comparison and Evaluation (RFP-3340) was published in FY 1982 to provide SWECS designers with a guide to the selection and use of available computer codes.

3.1 Small Systems Technology

Project Title

Dynamometer Testing

Management Rockwell International Terry J. Healy (303) 497-7111	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 to September 30, 1982
	FY 81 Funding FY 82 Funding $154,000 -0-[1]
Principal Investigator R.L. Moment (303) 497-7162	**CUMULATIVE FUNDING** $154,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Dynamometer testing is utilized to reveal many correctable SWECS problems that would have been found only through extended atmospheric test and then would have required correction and retest.

OBJECTIVE

To fully electrically test and characterize SWECS and any associated rotating mechanical drive trains.

APPROACH

All SWECS under test at Rocky Flats were dynamometer-tested prior to long term atmospheric testing. Problems discovered were brought to the attention of either the program monitor or the vendor for correction. The dynamometer will be used to test separate electrical and mechanical portions of the SWECS. Work was distributed across other research projects in FY 1982.

OUTPUT

An engineering report fully characterizing each generator andany associated drive train tested will be issued. The report will detail the test method employed and reference the standard source of test procedures. If standard procedures do not exist, details of test methodology are discussed. Dynamometer test data are published in regular machine test reports and will contribute to the Power Sybsystems Research project.

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[1] Distributed among research projects.

3.1 Small Systems Technology

Project Title

Controlled Velocity Testing

Management Rockwell International Terry J. Healy (303) 497-7111	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 to September 30, 1982
	FY 81 Funding $500,000 FY 82 Funding -0-[1]
Principal Investigator R. L. Moment (303) 497-7162	**CUMULATIVE FUNDING** $500,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Three test series of seven machines have demonstrated controlled velocity testing to be a practical method to accelerate evaluation of machine performance in terms of parametric variations. Since it can be completed in a relatively brief period, the method allows tests of a large number of machines in dedicated use to augment data gathered through atmospheric tests.

OBJECTIVE

- To assess the effects of changes in rotor and load parameters.
- To allow assessment of wind turbines for product improvement.

APPROACH

Tests are conducted at the DOT Transportation Test Center (TTC) at Pueblo, Colorado. SWECS are mounted on specially adapted flat-bed rail cars which are pushed by a locomotive to create predetermined wind velocities. Data gathered demonstrates power production capabilities but cannot determine parameters such as reliability under various climatic conditions. In FY 1982, work in this area was distributed across several research projects.

OUTPUT

Twelve machines were scheduled to undergo CVT in FY 1981. However, funding cuts reduced this figure to two. In FY 1982 data were released in final machine reports and contributed to aerodynamics and power subsystems research efforts.

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[1] Distributed among research projects.

3.1 Small Systems Technology

Project Title

Rocky Flats Atmospheric Testing

Management Rockwell International Terry J. Healy (303) 497-7111	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 to September 30, 1982
	FY 81 Funding FY 82 Funding $1,476,000 -0-[1]
Principal Investigator R.L. Moment (303) 497-7162	**CUMULATIVE FUNDING** $3,976,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Atmospheric testing of SWECS at the Wind Systems Test Site for periods of up to two years provides data from which the reliability, maintainability, safety and performance characteristics of machines can be assessed. The purpose of atmospheric testing includes this data generation as well as upgrading techniques to incorporate greater versatility to gather data on machine operations that have not been previously addressed.

OBJECTIVE

To obtain accurate, reliable and consistent data on SWECS configurations as an aid in SWECS selection based on siting characteristics, and in preparation of future special tests in anticipation of product improvement needs by industry.

APPROACH

Atmospheric testing of commercial SWECS at Rocky Flats included the collection of intensive and long term machine performance data with appropriate instrumentation under actual atmospheric conditions. Results of these tests are made available to the public and close liaison is maintained with machine manufacturers. Unreimbursed testing of commercial machines ended at the close of FY 1981. Work under this former project is not distributed across all research areas.

OUTPUT

Upon test completion, final reports, technical notes and memos are prepared on a timely basis. Also, failure reports or technical notes/papers relating to a particular aspects of machine operation of general interest to the SWECS community are made available to the public through the National Technical Information Service (NTIS).

[1] Distributed among research projects.

3.1 Small Systems Technology

Project Title

Assessment of Technology for Defining Research Requirements

Management Rockwell International A.R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 - September 30, 1982
	FY 81 Funding $195,000 FY 82 Funding $255,000
Principal Investigator A.C. Hansen (303) 497-7153	**CUMULATIVE FUNDING** $1,175,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Periodic reviews of industry's technology status are conducted to aid DOE's long term planning and R & D support activities.

OBJECTIVE

To determine current SWECS technology status and necessary long term federal R & D support activities.

APPROACH

Technology Assessment compared a number of earlier technology studies (economic impacts and feasibility studies for example) on the basis of information available in current literature. Studies were conducted to identify SWECS technology issues and determine actions to address them. Communications were maintained with leading SWECS experts and public interest groups. During FY 1982, additional analytical work on SWECS mechanical heating was performed.

OUTPUT

The studies were documented in an FY 1982 update of the FY 1980 SWECS Technology Assessment Report, and presented at the Fifth Biennial Wind Energy Conference and Workshop.

3.1 Small Systems Technology

Project Title
Vibration Testing

Management Rockwell International Terry J. Healy (303) 497-7111	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 to September 30, 1982
	FY 81 Funding FY 82 Funding $154,000 -0-[1]
Principal Investigator R.L. Moment (303) 497-7162	**CUMULATIVE FUNDING** $154,000
WORK LOCATION DOE Rocky Flats Plant Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

The testing of various SWECS components can yield a large amount of information relevant particularly to structural integrity and machine reliability.

OBJECTIVE

To identify potential sources of failure and attempt to predict the life expectancy of components under cyclic loading.

APPROACH

Vibrarion tests are conducted primarily on the rotor blade, the tower, and on the system as a whole. Data are compared with rotational speeds to determine resonant response problems. Fatigue tests can be conducted on any component which is subjected to cyclic loading to predict or determine its life expectancy. Work was distributed across other research projects in FY 1982.

OUTPUT

Results of vibration rests which are pertinent to a machine are included in final machine reports. Results of vibration or fatigue tests that are not associated with a particular machine as, for example, the variations in vibrational characteristics of wooden blades, are reported in technical notes or papers.

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[1] Distributed among research projects.

3.1 Small Systems Technology

Project Title

Electrical Stability Control and Performance Improvement

Management Rockwell International A. R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1981 - September 30, 1982
	FY 81 Funding $-0- ***FY 82 Funding*** $853,000
Principal Investigator J. C. Balcerak (303) 497-7139	**CUMULATIVE FUNDING** $853,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Most small wind systems are designed for interconnection with a utility grid. As the number and penetration of interconnected wind systems increases, utility and user concerns center on control, switching operation effects, power quality and equipment protection, all of which can affect system safety and wind system reliability. Further, it is known that wind system generator efficiency is generally poor, particularly when constant rpm wind turbine rotors are employed.

OBJECTIVE

- Increase annual energy production of small wind systems by 30 percent through advanced electrical design of generation, control, and energy management subsystems.

APPROACH

Work in FY 1982 focused on the design, fabrication, and testing of a variable speed, constant frequency (VSCF) generation system which has the potential to resolve many of the remaining utility interconnection issues. The VSCF hardware developed at Rocky Flats consists of a wound rotor induction generator controlled by a synchronous inverter and a microcomputer. The system was tested on a 5-meter Darrieus wind turbine under controlled velocity conditions. Subsequent research will include an investigation of switching hardware and an examination of multiple system operations.

OUTPUT

The operation of the VSCF will be documented in a 1983 report which will include test data from the Darrieus testbed. The final VSCF report will fully document the design and include information on performance with horizontal axis wind systems and the optimization of generator performance and control characteristics.

3.1 Small Systems Technology

Project Title

Fatigue Modeling and Failure Analysis

Management Rockwell International A. R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1981 - September 30, 1982
	FY 81 Funding -0- ***FY 82 Funding*** $643,000
Principal Investigator M. P. Schroeder (303) 497-7166	**CUMULATIVE FUNDING** $643,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Over half of the documented small wind system failures have been directly attributed to blade/hub fatigue. Six generic types of high stress/low cycle and low stress/high cycle fatigue have been involved. No validated analytical techniques exist for predicting fatigue loads likely to be encountered or for predicting fatigue life.

OBJECTIVE

- Develop and verify techniques for estimating stress loads and component fatigue life to enable effective selection and sizing of components to avoid fatigue failure.

APPROACH

Fatigue testing of one horizontal wind system is being performed to obtain measurements of blade root strains, rotor rpm, strongback acceleration, and natural frequencies for comparison with concurrent wind characteristics. Observed strains will be correlated with sources of cyclic and irregular loading. Fatigue load spectra will be developed for use in cycle counting and applying load magnitudes and cycle figures to the prediction of fatigue life. Multiple system testing and analysis will follow.

OUTPUT

Initial load data were obtained for the first test machine in FY 1982. These will be compared with predictions using available methods in a report to be issued in 1983, which will initiate the development of a universal fatigue prediction method. After refinement, two fatigue prediction methods will be issued, one for wind systems fatigue and the other for tower fatigue.

3.1 Small Systems Technology

Project Title

Rotor Aerodynamics Prediction, Validation and Enhancement

Management Rockwell International A. R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1981 - September 30, 1982
	FY 81 Funding -0- ***FY 82 Funding*** $710,000
Principal Investigator W. S. Bollmeier, II (303) 497-7169	**CUMULATIVE FUNDING** $710,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Performance improvements of 20-30 percent could be realized by optimizing rotor performance. Existing wind turbine design and performance prediction methods are subject to large errors at high and low wind speeds. Most designs are "time-proven" airfoils which may not be the best choice for specific rotor control systems and generator/gearbox configurations. In addition, poor yaw tracking can rob some wind systems of substantial amounts of energy.

OBJECTIVE

- Increase wind system energy output by 20 percent by improving aerodynamic performance through development of rotor and blade performance prediction techniques, acquisition of reliable airfoil performance data, and development of high performance and special purpose airfoils.

APPROACH

Data for use in analytical model development/improvement, the evaluation of high performance and special purpose airfoils, and the assessment of yaw control effects will be collected using the controlled velocity testing technique. Blade pressure distribution measurements will be made to establish accurate pressure distribution of the Eppler Airfoil Code and blade load predictions of the PROP 6 code and ensure their overall applicability to accurate rotor system models.

OUTPUT

The Performance Model Comparison Study performed by four contractors will be evaluated to identify potential improvements in existing models. Promising high performance and special purpose airfoils will be identified in reports documenting fabrication efforts and test results, together with analytical comparisons with currently used airfoils. Prediction code refinements and blade pressure studies will lead to the development of a rotor design handbook in 1984.

3.1 Small Systems Technology

Project Title

Static and Dynamic Structural Analysis, Research and Validation

Management Rockwell International A. R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1981 - September 30, 1982
	FY 81 Funding / ***FY 82 Funding*** $-0- / $850,000
Principal Investigator M. P. Schroeder (303) 497-7166	**CUMULATIVE FUNDING** $850,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Structural response characteristics are important factors governing wind system safety, reliability, and useful life. Of observed wind system failures, at least 45% are attributable to static and/or dynamic loads. Past Rocky Flats development projects show that structural loading conditions are design and cost drivers. RF projects on tower dynamics, dynamics stall, and yaw control have shown current theoretical models are inadequate and treat major subsystems as separate or uncoupled systems.

OBJECTIVE

- Develop an accurate assessment of structural loadings encountered by wind systems in all operating conditions as a function of both wind inputs and machine configurations.
- Develop reliable technologies for predicting wind system structural responses.

APPROACH

Work was performed in three major areas (rotor dynamics, tower dynamics, and yaw control) toward the perfection of existing codes to include coupled systems dynamics factors. Dynamics and loads of parked rotors during high wind/survival conditions were measured and analyzed for wind turbines using feathering and stalling overspeed protection methods. In addition, controlled velocity testing was used to collect data on the reduced loads caused by yaw tracking errors.

OUTPUT

A preliminary analytical model incorporating yaw motion and pitch, flap, and speed variations and effects was developed for predicting aeroforces and moments on the rotor. The ultimate output of this project will be an analytical model, incorporating coupled system dynamics, for use by designers in efficiently optimizing system life. In 1983, the fatigue modeling effort (below) will be incorporated.

3.1 Small Systems Technology

Project Title

Yaw Control

Management Rockwell International D.C. Shepherd (303) 497-7167	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Science Applications, Inc. 1764 Old Meadow Lane McLean, Virginia 22102	***Period of Performance*** October 1, 1980 to September 30, 1982
	FY 81 Funding FY 82 Funding $38,000 -0-
Principal Investigator N/A	**CUMULATIVE FUNDING** $231,500
WORK LOCATION Contractor's Facility	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Yaw control functions range from simple positioning of the wind turbine for maximum energy capture to the control of the system output and operating speeds. A systematic analysis of various configurations will aid in the selection and design of more reliable and effective yaw control techniques.

OBJECTIVE

To develop analysis procedures to aid SWECS designers in selecting and designing reliable and cost effective yaw control sybsystems.

APPROACH

The project is being conducted under contract in two phases. During the first phase, the contractor will identify and generically group all known yaw control devices or new concepts according to their basic operating principals. In phase two, static and dynamic analyses on each group will be made and a simplified analytical methodology to determine load characteristics and reliability will be developed.

OUTPUT

A technical report will be published in FY 1983 that describes a set of procedures for determining such yaw control design characteristics as yaw rates, dynamic loads, and performance effects. The methodology and information developed shall be usable without the use of large computer programs or models.

3.1 Small Systems Technology

Project Title

Evaluation of Pumps for Wind-Driven Irrigation

Management USDA-ARS R.N. Clark (806) 378-5721	**CONTRACT NO.** DE-AI01-76ET20319
Contractor Science Applications, Inc. 1764 Old Meadow Lane McLean, Virginia 22102	***Period of Performance*** 18 months ***FY 81 Funding*** -0- FY 82 Funding -0-
Principal Investigator P.L. Marjon	**CUMULATIVE FUNDING** $76,000
WORK LOCATION Albuquerque, New Mexico	**CONTRACTING OFFICE** USDA-ARS, Conservation and Production Research Laboratory, Bushland, Texas

PROJECT SUMMARY

BACKGROUND

Pumps are presently designed to operate at constant RPM and constant torque. Mechanical drive wind turbines produce either variable RPM, variable torque, or both, therefore, if either RPM or torque are reduced low enough, no water flows from the pump. This is the first phase of studies needed to design a complete wind-powered pumping system.

OBJECTIVE

To identify, through assessment of the operating and performance characteristics, the best type(s) of pumps to be used in wind-powered irrigation systems.

APPROACH

A contract was enacted in late FY-80 to perform this study. The contractor will review the operating characteristics of all pumps and evaluate them for operation at varying speed and power. All pumps will be ranked for three different types of pumping systems. Recommendation will be made as to which types of pumps should be used in future irrigation experiments.

OUTPUT

Final report has been prepared, revised, and will be ready for distribution in FY-83.

3.1 Small Systems Technology

Project Title

Airfoil Data Catalog

Management Rockwell International D. C. Shepherd (303) 497-7167	CONTRACT NO. PFY-12781-W
Contractor Texas A&M University College Station, Texas 77843	*Period of Performance* October 1, 1980 - September 30, 1982
	FY 81 Funding $35,000 *FY 82 Funding* -0-
Principal Investigator S. J. Miley (713) 545-7541	CUMULATIVE FUNDING $73,100
WORK LOCATION Contractor's Facility	CONTRACTING OFFICE Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

The unavailability of low Reynolds number airfoil performance data for commonly used airfoils has been a significant stumbling block to SWECS designers. The accuracy of predicting rotor performance strongly depends on the airfoil input data which presently comes from widely dispersed sources, some of which are not in agreement for a given airfoil.

OBJECTIVE

- To develop a low Reynolds number airfoil data catalog for application to wind turbine performance analysis and design.

APPROACH

This project was initiated in FY 1979. Following an extensive literature survey of both U.S. and foreign sources, the contractor developed tabular airfoil characteristics from experimental curves using numerical data smoothing and interpolation techniques. Following this the contractor prepared the data in a catalog format. For each source of data, the testing method and conditions are described.

OUTPUT

A catalog of all readily available data of airfoil characteristics for Reynolds numbers less than 3 million was published in 1982. The data are organized according to thickness and camber, and include both laminar and turbulent flow airfoils.

3.1 Small Systems Technology

Project Title

Measurement of Farm Loads

Management USDA-ARS R. N. Clark (806) 378-5721	**CONTRACT NO.** DE-AI01-76ET20319
Contractor USDA-ARS	***Period of Performance*** 3 years
	FY 81 Funding $100,000 — FY 82 Funding $70,000
Principal Investigator Leo Soderholm (515) 294-5723	**CUMULATIVE FUNDING** $170,000
WORK LOCATION Ames, IA	**CONTRACTING OFFICE** USDA-ARS, Conservation and Production Research Laboratory, Bushland, TX

PROJECT SUMMARY

BACKGROUND The electrical use patterns of farm power applications are largely unknown in relation to specific agricultural production systems. These patterns of rural electric power use are an essential element in the development of wind systems for supplying the diversified electrical loads from wind systems and for the development of reliable economic analyses of wind application potential. These load patterns also are important for providing data and for determining design criteria for controls and control systems to implement the interfacing of SWEC's to farmstead loads.

OBJECTIVE To develop data on the electrical use and demand of farmstead loads to provide a data base of electrical power requirements and patterns of use for agricultural production units.

APPROACH The load patterns of the electrical use on farms will be determined for various agricultural production activities by specialized metering including multiple-register meters and tape demand units. From these measurements, the electrical power use of agricultural loads will be compiled to determine electrical system requirements, the energy and load management contribution of wind systems to farmstead power requirements will be assessed, and a data base will be provided for economic analyses of wind system application in agriculture.

OUTPUT

1. Report of research on farmstead load measurement at end of study
2. Base data on farm electrical load power requirements
3. Base data on farm electrical load patterns of use

3.1 Small Systems Technology

Project Title

Wind-Assist Deep-Well Irrigation Pumping

Management USDA-ARS R. N. Clark (806) 378-5721	**CONTRACT NO.** DE-AI01-76ET20319
Contractor USDA-ARS and West Texas State University	***Period of Performance*** 3 years
	FY 81 Funding FY 82 Funding $220,000 $190,000
Principal Investigator R. Nolan Clark (806) 378-5721	**CUMULATIVE FUNDING** $410,000
WORK LOCATION Bushland, TX	**CONTRACTING OFFICE** USDA-ARS, Conservation and Production Research Laboratory, Bushland, TX

PROJECT SUMMARY

BACKGROUND Since about 70 percent of the irrigation pumps in the Southern Plains are powered by internal combustion engines, a need exists to see if wind turbines can be used to assist these engines. All linkages must be done mechanically with simplified controls. There is a need to obtain performance data on one of the new designed low cost vertical-axis wind turbines. The irrigation application was selected because of high kilowatt demand and availability of 3 phase, 480 volt power.

OBJECTIVE (1) Obtain actual performance data on the operation of a wind turbine mechanically coupled to a deep-well irrigation pump to assist a diesel engine and (2) obtain actual performance data on the operation of a 17-meter, vertical-axis wind turbine when generating power for a deep-well electric irrigation pump.

APPROACH The 40-kW vertical-axis, wind turbine at Bushland, TX will be used in this study. A 60-kW diesel engine and dual drive gearhead have been installed at the well site and initial testing has started. The pumping rate, wind power, torque, and fuel consumption are being measured to characterize the performance of the wind turbine and diesel engine and to determine the fuel savings of a wind-assisted system. A 17-meter low cost, vertical-axis wind turbine has been installed near an irrigation pump and two center pivot sprinkler systems. Electricity produced by the wind turbine will be either used by the irrigation system or fed to the electrical utility.

OUTPUT

1. Design criteria for mechanical drive wind turbine
2. Report of wind-assisted diesel irrigation pumping to be written at end of study
3. Performance of 17-meter vertical-axis wind turbine
4. Report of operational experiences with 17-meter turbine

3.2 Intermediate and Large Systems Technology

Project Title

Low-Cost, Stainless Steel/Fiberglass-Foam Wind Turbine Blades

Management	**CONTRACT NO.**
P. Finnegan (216) 433-4000	DEN3-129
Contractor	***Period of Performance***
The Budd Company 375 Commerce Drive Fort Washington, PA 19034	1979-1983
	FY 81 Funding -0- FY 82 Funding -0-
Principal Investigator	**CUMULATIVE FUNDING**
W. Eggert (215) 643-2950	$399,580
WORK LOCATION Fort Washington, PA	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

This contract was prompted by the need for the development of more economical Mod-0A wind turbine blades. A variety of materials were considered including a steel spar combined with a fiberglass aerodynamic shape. Key problems associated with this study include the design of a steel spar manufactured in continuous full blade length joined by means of spot welding to provide long-term fatigue performance.

OBJECTIVE

The objective of this study is to identify and develop a Mod-0A, low-cost, fatigue-resistant, stainless steel spar/fiberglass-shell wind turbine blade design.

APPROACH

This contract, awarded to the Budd Company, was one of three studies initiated for the development of low-cost, Mod-0A blades. This contract was organized into Phase I blade design, and Phase II blade fabrication efforts. Included in the Phase I effort is the design and delivery of a full-scale root end blade section for fatigue testing. The blade design effort proceeded from a preliminary to final design sequence with periodic technical reviews. The contract effort also included the development of spot welded stainless steel static and a fatigue design data base.

OUTPUT

The output of this contract includes the delivery of a design of a low-cost, stainless steel spar/fiberglass-foam shell blade, static and fatigue data, a full-scale, root end blade section for fatigue testing, and a final report. The full scale root end blade section was delivered to NASA and tested in FY 1982. Testing was terminated due to a weld crack at the transition of the spar to the root end fitting. Redesign of the entire transition section would be required. As a result, the Phase II effort will not be implemented. Publication of the final report is planned in FY 1983.

3.2 Intermediate and Large Systems Technology

Project Title

Construction and Test of a 300 kW Variable Speed Synchronous Generator

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** DEN3-243
Contractor Bogue Electric Manufacturing Company 100 Pennsylvania Avenue Paterson, New Jersey 07507	***Period of Performance*** 1981 to 1982 ***FY 81 Funding*** FY 82 Funding $420,000 $73,266
Principal Investigator B. Barron (201) 523-2200	**CUMULATIVE FUNDING** $493,266
WORK LOCATION Paterson, New Jersey	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

A variable-speed, constant-frequency machine is an appropriate type generator for a wind turbine because of the continually varying character of the wind. It is expected that such a machine will not only generate higher quality power than conventional machines, but will also reduce the cost of electricity generated by virtue of reducing structural requirements and by maximizing energy capture.

OBJECTIVE

The effort provides for the design and fabrication of a variable-speed, constant-frequency generator for use in a wind turbine. The resulting system is to be operated synchronously with commercial utility networds at any wind turbine rotor speed within a specified speed range.

APPROACH

The Bogue Electric Manufacturing Company was selected to design, fabricate and deliver to NASA a variable-speed, constant-frequency generator using a wound rotor induction machine with a cycloconverter on the rotor to transfer slip power into and out of the rotor at the correct frequency. The cycloconverter and the rotor exciter will be rotating units mounted on the same shaft as the machine rotor.

OUTPUT

The design was partially completed in FY 1982. However, due to technical problems and uncertainties, projected costs exceeded planned funding, and action to terminate the contract and stop work was initiated in FY 1982.

3.2 Intermediate and Large Systems Technology

Project Title

Wind Energy Remote Data System Operational Data

Management D. Spera (216) 433-4000	**CONTRACT NO.** DEN3-316
Contractor Fairchild Weston Systems P.O. Box 10249 Sarasota, Florida 33578	***Period of Performance*** 1976 to 1985
	FY 81 Funding $720,000 FY 82 Funding $445,000
Principal Investigator J. Matthews (202) 933-2100	**CUMULATIVE FUNDING** $3,435,000
WORK LOCATION DOE/NASA Wind Turbine Sites	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

Each experimental wind turbine requires, during startup, highly reliable online data processing of information from over 90 separate transducers and subsequent long term monitoring of about 40 parameters. The Wind Energy Mobile Data System has supported the initial startup of four Mod-OA machines, the Mod-1, the first three Mod-2 units, the DOI/SVU machines (Mod-2 and WTS-4), and the privately developed WTG and Bendix Wind turbines. It is planned to support the Mod-5A and Mod-5B during initial start-up. The Wind Energy Remote Data System also provides long term data support for the three Mod-2 units and the DOI/SVU machines.

OBJECTIVE

The objective of this task is to acquire, process and analyze the engineering data generated during all wind turbine operations and to convert these data into useful information.

APPROACH

NASA opted for a balanced mix of mobile and stationary data systems. This allowed for the full range data processing capability required to support each machine as it is assembled and brought into operation, without incurring the high cost of duplicating this equipment at each site. In addition, a minimum of data equipment is retained at each site over the long term to monitor the continuing performance of each wind turbine. The operation and maintenance of the remote portions of this data system are performed by Fairchild Weston Systems personnel under NASA direction. This provides for a fully integrated operational data system for the initial start-up through the long term evaluation of all designated WTs.

OUTPUT

The major result of the effort is the information required by field engineers to bring a new machine into operation, by project managers to assess machine status and performance, and by design engineers for development evaluations.

3.2 Intermediate and Large Systems Technology

Project Title

Development of Advanced Wood Composite Blade Technology Wood Composite Tip-to-Tip Rotor

Management	**CONTRACT NO.**
P. Finnegan (216) 433-4000	DEN3-260
Contractor	***Period of Performance***
Gougeon Brothers, Inc. Bay City, MI	1981-1983
	FY 81 Funding $532,109 FY 82 Funding 186,886
Principal Investigator	**CUMULATIVE FUNDING**
T. Stroebel (516) 684-7286	$718,995
WORK LOCATION	**CONTRACTING OFFICE**
Bay City, MI	NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

This task was initiated in FY 81 to provide a wood composite tip-to-tip rotor equipped with a teetering hub for research evaluation by NASA LeRC. Key problems associated with this rotor include the analysis and estimation of teetering loads, the design of a teetering hub system and its installation into the wood rotor structure. The rotor will be designed to have a field splice in order to develop a joining technology that will be needed for large wood composite multi-megawatt rotors.

OBJECTIVE

The objective of this contract is to develop and deliver a 90 ft. tip-to-tip wood composite rotor and test specimens. The test specimens will be used for the development of a fatigue data base for designing wood composite rotors and blades. In addition other test specimens include an inner rotor as well as a finger joint specimen for design qualificatior testing.

APPROACH

The design of the rotor will proceed from a conceptual to a final design sequence with design reviews conducted by the Government. The testing of the specimens will be conducted at laboratories to be selected by the Government. The funding shown above is for the Phase I effort that includes the design of the complete rotor system and specimens, and the design and fabrication of rotor manufacturing tooling. It is anticipated that the funding for the Phase II effort, the fabrication of the rotor, will be provided prior to the completion of the final rotor design review.

OUTPUT

The output of this contract includes the delivery of a 90 ft. dia. tip-to-tip rotor, laminates for the fabrication of laboratory wood composite and load takeoff stud specimens for the development of a design data base, inner rotor and finger joint test specimens for qualification of the teetering hub system and the field splice joint, respectively, and topical and final reports. It is anticipated that these deliverable items will provide an analytical as well as a fabrication experience basis for the design of future, low-cost, multi-megawatt rotor systems.

3.2 Intermediate and Large Systems Technology

Project Title Development of Fiberglass Composite Fatigue Data for the Design of Fiberglass Composite Wind Turbine Blades

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** DEN3-182
Contractor IIT Research Institute Chicago, IL 60616	***Period of Performance*** 1979-1982 ***FY 81 Funding*** $28,000 FY 82 Funding $0
Principal Investigator K. Hofer (312) 567-4000	**CUMULATIVE FUNDING** $80,850
WORK LOCATION Chicago, IL	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

The lack of a design fatigue data base prompted the initiation of a study to develop TFT (transverse filament tape) fiberglass fatigue data for the design of future structurally-efficient, fiberglass wind turbine blades. The key problem associated with this study includes the design of a laboratory-type fatigue specimen that will simulate the composite blade structure, including the complex filament-wound wrap pattern used for fiberglass TFT wind turbine blade manufacturing.

OBJECTIVE

The objective of this program is to develop a TFT fiberglass static and fatigue property data base for the design of future TFT fiberglass wind turbine blades.

APPROACH

Simulated TFT fiberglass blade laminates were fabricated under DEN3-101 (Mod-0A TFT fiberglass blades). Laminates were made using the epoxy resin used for the fabrication of the low-cost, Mod-0A blades, as well as a low-cost polyester matrix resin. The effects of these two types of resin on fatigue performance would be determined IIT Research Institute used these laminates to fabricate and subject specimens to static and fatigue tests. The cyclic fatigue tests will be designed to provide a series of SN curves that include the blade fatigue loading conditions under long-term power generation conditions.

OUTPUT

The final report, NASA CR-165566, provides a preliminary data base for the design of future TFT wind turbine blades. The results of this project verified that the Mod-0A TFT fiberglass blades were designed with a satisfactory fatigue margin. The final report was completed and distributed in FY 82.

3.2 Intermediate and Large Systems Technology

Project Title

Development of a Methodology for Horizontal Axis Wind Turbine Dynamic Analysis

Management D. Spera (216) 433-4000	**CONTRACT NO.** Grant No. NSG-3303
Contractor Massachusetts Institute of Technology Department of Aeronautics & Astronautics Cambridge, MA 02139	***Period of Performance*** 1979-1982 ***FY 81 Funding*** $69,994 FY 82 Funding $69,962
Principal Investigator J. Dugundji (617) 253-3758	**CUMULATIVE FUNDING** $205,858
WORK LOCATION Cambridge, MA	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH 44135

PROJECT SUMMARY

BACKGROUND

Wind turbines are complex aeroelastic structures which require specialized analysis tools for design verification. Continuing evaluation and upgrading of these tools are required to maintain state-of-the-art analysis capability.

OBJECTIVE

The objective is to improve state-of-the-art design tools for the determination of horizontal axis wind turbine dynamic characteristics.

APPROACH

Existing computer programs for system dynamic analysis, such as the MOSTAS code, developed by Paragon Pacific, Inc., will be independently reviewed. Potential areas for improvement will be identified. Simple models for solving specific stability and response problems will be developed. Key stability behavior will be investigated experimentally by wind tunnel testing.

OUTPUT

Periodic research reports and papers were published as a result of this study, providing theoretical analysis, design guidelines, and experimental data support. The reports include NASA CR-165385, MIT ASRL TR 197-3, and MIT ASRL TR 197-4 and a paper was published in NASA CP-2185.

3.2 Intermediate and Large Systems Technology

Project Title

Mod-0 Experimental Research

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** In-house
Contractor NASA	***Period of Performance*** 1974-1985
	FY 81 Funding $1,100,000 FY 82 Funding $1,100,000
Principal Investigator J. Glasgow (216) 433-4000	**CUMULATIVE FUNDING** $7,800,000
WORK LOCATION Sandusky, OH	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

The research and technology base for modern high tip speed wind turbines is very limited. A continuing need exists to gather research data applicable to large wind turbines to fulfill this need. Operational data gathered in research tests can be used to verify or refute theoretical predictions and lead to new insights and development of the technology. The Mod-0 wind turbine was installed for this purpose in 1975 and continues in this capacity.

OBJECTIVE

The objectives are: (1) to identify and resolve problems encountered in the operation of large wind turbines and develop an understanding of the operation of large wind turbines; (2) to investigate the feasibility of advanced design concepts and subsystems; and (3) to provide experimental data to verify aerodynamic performance, structural dynamics, power train dynamics, and system dynamics computer codes.

APPROACH

The 1982 research emphasis focused on direct comparisons of several rotor configurations in various operating modes. The test data collected accurately determined the effects of a Delta-3 hinge, the airfoil shape, surface roughness of the airfoil, rotor speed and yaw rate on the performance including operation in the stall regime. It also included the evaluation of the yaw forces, teeter and yaw motion while operating with a free yaw rotor.

OUTPUT

The results of the Mod-0 research tests are reported in reports and papers. In 1982 these reports included: TM-82750 - Variable Gain for a Wind Turbine Pitch Control by R.C. Seidel and A.G. Birchenough & TM-82870 - Measured Performance of a Tip-Controlled Teetered Rotor with a NACA 643-618 Tip Airfoil by R.D. Corrigan. Additional reports, a result of tests during FY 82, will be published in FY 83.

3.2 Intermediate and Large Systems Technology

Project Title

Teetered, Tip-Controlled Rotor for Mod-0 Test Design, Evaluation and Test

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** In-house
Contractor NASA	***Period of Performance*** 1978-1980
	FY 81 Funding $20,000 FY 82 Funding $0
Principal Investigator John C. Glasgow (216) 433-4000	**CUMULATIVE FUNDING** $400,000
WORK LOCATION Cleveland, OH	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

Horizontal axis wind turbines have traditionally used two means of power control: (a) the stalling of a blade which has a fixed preset pitch angle which occurs as the wind speed increases, or (b) the use of a fully pitchable blade. As rotors become larger it is more attractive to consider moving the tip of the blade in pitch. However, the research and technology base is very limited in this area.

OBJECTIVE

The objective is to verify the teetered tip rotor control analysis techniques, primarily those being used to design Mod-2.

APPROACH

The approach is to calculate the performance of a teetered tip control rotor for Mod-0, calculate loads and control rates, design blades and tip control, fabricate blades, test and evaluate the results and analytical techniques.

OUTPUT

Tests in support of Mod-2 were completed in the first quarter of FY 81. The test results were analyzed and reported in DOE/NASA 1028-31, thereby completing this project.

3.2 Intermediate and Large Systems Technology

Project Title

Power Train Design - Cost/Analysis

Management	**CONTRACT NO.**
P. Finnegan (216) 433-4000	In-house
Contractor	***Period of Performance***
NASA	1979-1982
	FY 81 Funding $100,000 FY 82 Funding $110,000
Principal Investigator	**CUMULATIVE FUNDING**
J. M. Savino (216) 433-4000	$310,000
WORK LOCATION	**CONTRACTING OFFICE**
Cleveland, OH	NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

New drive train concepts are required to reduce costs, reduce cyclic loads, increase reliability, and improve power quality. There is a need to improve the techniques for dynamic drive train analysis to calculate loads, stability, and power quality, and to analyze drive train concepts in a consistent manner to assure the validity of the results of tradeoff studies which are intended to identify the most promising concepts.

OBJECTIVE

The objective is to identify drive train concepts which will result in a net reduction in the cost of energy.

APPROACH

This work will be performed in support of current designs and of future designs such as Mod-5. Several drive train configurations will be analyzed and tested: rotor on gearbox, epi-cyclic gears, phase shifting dampers, two-speed rotors, and other concepts. Drive trains will be conceptually designed, weight estimates made, and dynamic characteristics determined. The dynamics of the drive train will be analyzed using codes that have been verified by Mod-0 research machine. The results will be incorporated into the wind turbine studies to determine the net benefit.

OUTPUT

A two-speed generator was tested. The overall performance and operating characteristics for two-speed operation was successful. A report was published in FY 82. Tests were run with an induction generator with 3.8% slip. Results showed attenuation of drive train oscillations comparable to those produced by a fluid coupling. A concept design study of a 400 kW machine showed that a gearbox used to support a fixed pitch rotor with an inductor generator has good design and cost effective potential for use on an intermediate size wind turbine.

3.2 Intermediate and Large Systems Technology

Project Title

Mod-0 Conceptual Design Studies Experimental 200 kW Wind Turbine

Management	**CONTRACT NO.**
P. Finnegan (216) 433-4000	In-house
Contractor	***Period of Performance***
NASA	1978-1981
	FY 81 Funding $20,000 FY 82 Funding $0
Principal Investigator	**CUMULATIVE FUNDING**
J. Savino (216) 433-4000	$140,000
WORK LOCATION	**CONTRACTING OFFICE**
Cleveland, OH	NASA-Lewis Research Center

PROJECT SUMMARY

BACKGROUND

There is a need to continually update the basic Mod-0 configuration to simulate advanced WT designs. In addition, there is a need to integrate the experience obtained as a result of Mod-0, Mod-0A and Mod-2 operations and tradeoff studies, and rotor, power train and control studies. This experience indicates there is potential to reduce wind turbine costs by incorporating advanced wind turbine modifications, but a wind turbine study is required to determine the magnitude of the reduction.

OBJECTIVE

The objective of the conceptual design studies was to prepare a conceptual design of a low-cost 200 kW wind turbine design which integrates NASA wind turbine experience and provides the basis for both an advanced production WT and for upgrading of the experimental Mod-0 turbine at Plum Brook.

APPROACH

The approach was to conduct a sequence of in-house design and cost study interactions until an acceptably low-cost design was achieved. Each iteration consisted of a design effort in which th expensive subsystems are eliminated, redesigned, or replaced by a lower cost alternative and then assessed for their potential low-cost effectiveness. Appropriate industries were used to provide costs for fabrication, assembly and erection.

OUTPUT

One potential low-cost design concept was identified as a guyed-cylindrical steel tower on a prefabricated concrete pedestal with grouted anchors for the guys. Two reports, NASA TM-82804 and NASA CR-165589, summarizing results of the study to develop a low cost tower and foundations were published in FY 1982.

3.2 Intermediate and Large Systems Technology

Project Title Three Dimensional Aerodynamic Flow Regimes over Rotor Airfoil Surfaces

Management P. Finnegan, (R&TD) 216-433-4000	**CONTRACT NO.** In-house
Contractor NASA	***Period of Performance*** 1982 - 1984
	FY 81 Funding $0. FY 82 Funding, $40,000
Principal Investigator T. W. Nyland, 216-433-4000	**CUMULATIVE FUNDING** $40,000
WORK LOCATION Sandusky, Ohio	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

Current rotor blade performance data show that airfoil stall does not occur at the predicted angles of attack for the measured wind velocities and rotor speeds. As a result, the measured power, produced by the rotor at high angles of attack, is significantly higher than predicted. It is believed that airflow, on the low pressure side of the airfoil, moves radially toward the blade tip causing coriolis forces that delay flow separation and stall.

OBJECTIVE

The objective of this research is to develop a data base, that currently does not exist, on the secondary flow distribution on the low pressure side of rotor blade airfoils.

APPROACH

Research instrumentation will be installed on the Mod-0 rotor blades to measure airfoil pressure and air flow distributions. Experiments will be conducted, using Mod-0, to assess the measured aerodynamic characteristics of the rotor blade airfoil at high angles of attack. A variety of parameters will be measured during each experiment including wind velocity, rotor speed, blade angle of attack and measures of rotor performance. These experiments will be conducted in transient and high velocity wind conditions. Existing Mod-0 research data gathering, reduction and processing hardware/software will be utilized.

OUTPUT

A report will be published at the end of the fourth quarter of FY 1984 on the results of this research. The report will describe the design, fabrication and installation of special instrumentation on the rotor blades, and special methods for data gathering. The processed experimental data will be presented. A discussion of the results and conclusions, drawn as a result of this research, will be presented in the report.

3.2 Intermediate and Large Systems Technology

Project Title

One-Blade Rotor for Test on Mod-0

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** In-house
Contractor NASA	***Period of Performance*** 1979-1984
	FY 81 Funding $15,000 FY 82 Funding $15,000
Principal Investigator L. Viterna (216) 433-4000	**CUMULATIVE FUNDING** $30,000
WORK LOCATION Sandusky, OH	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

A one-bladed rotor operates at about 30 percent higher rpm than a two-bladed rotor with a consequent reduction in gearbox size and weight. In addition, the tower weight may be lower because the blade is shielded by the tower in hurricane winds and the loads transmitted to the tower are reduced. The rotor cost will be less. However, a one-bladed rotor captures 15 percent less energy than a two-bladed rotor of the same diameter and it may introduce system dynamic problems. Work is needed to define wind turbine performance, system dynamics and wind turbine control and operating characteristics.

OBJECTIVE

The objective of the project is to provide performance and dynamic information for assessing the relative merits of one-bladed wind turbines compared to multi-bladed wind turbines.

APPROACH

To acquire data on performance, dynamic, and operating characteristics of a one-bladed wind turbine, a project will be initiated to design, construct and test a one-bladed rotor using the Mod-0 as the test bed. The data from these tests will be analyzed and used to define the major technical advantages and risks associated with the one-bladed rotor. Tests will be aimed at identifying and solving technical problems associated with this rotor concept. Operational and performance characteristics will be reported at the conclusion of the project.

OUTPUT

A conceptional design of the rotor counterweight and support arm has been completed in FY 1981 under a university grant. This design is being used to modify existing rotor hardware and blades to complete the rotor. Contracts have been awarded for machining of the counterweight. Tests are planned for FY 83 with reports to follow in FY 84.

3.2 Intermediate and Large Systems Technology

Project Title

Rotor Blade Tip Configuration Effects on Performance

Management P. Finnegan (R&TD), 216-433-4000	**CONTRACT NO.** In-house
Contractor NASA	***Period of Performance*** 1982 - 1985
	FY 81 Funding $0.0 FY 82 Funding, $25,000
Principal Investigator J. M. Savino, 216-433-4000	**CUMULATIVE FUNDING** $25,000
WORK LOCATION Oahu, Hawaii Sandusky, Ohio	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

In recent years, aircraft fuel efficiency has been greatly improved thru the use of various devices on the wing tips that significantly reduced the induced drag of the wings. Semi-circular tips on a Mod-0A rotor decreased the cut-in velocity by 1 meter per second and measureably improve the rotor performance over most of the operating range. About five wing tip devices are known to improve aircraft performance and have potential for improving rotor performance.

OBJECTIVE

Identify rotor blade tip configurations that significantly improve the performance, and thereby increase the energy capture.

APPROACH

Various tip configurations will be fabricated and installed on a pair of rotor blades. Using the Mod-0 experimental wind turbine the rotor performance will be measured at speeds between cut-in and rated. The measured results will be compared with the performance of the same blades with a square tip, the reference case.

OUTPUT

The blade tip experiments conducted on the Mod-0A machine at Hawaii will be discussed in a report completed in the 2Q FY 1983. At the end of 2Q FY 1984, a report on the performance of at least two other configurations, tested on Mod-0 will be completed.

3.2 Intermediate and Large Systems Technology

Project Title

Visualization Studies of the Air Flow through a Rotor

Management	**CONTRACT NO.**
P. Finnegan (R&TD) (216) 433-4000	In-House
Contractor	***Period of Performance***
NASA	1982 to 1985
	FY 81 Funding -0- / FY 82 Funding $20,000
Principal Investigator	**CUMULATIVE FUNDING**
J.M. Savino (216) 433-4000	$20,000
WORK LOCATION Sandusky, Ohio	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

Existing rotor performance models cannot accurately predict the cut-in wind speed of a rotor. The Vortex Wake model is postulated on the existance of a helical vortex surface in the wake. The Blade Element-Momentum model assumes there is a smooth expanding air stream that passes thru the rotor. Experience with helicopter rotors has shown that under a zero power condition, the flow field thru and around the rotor is radically different than the flow patterns on which the models are postulated. To improve both the Blade Element-Momentum model and the Vortex Wake model will require a more realistic knowledge of the true flow patterns thru the rotor.

OBJECTIVE

Determine the true flow patterns thru the rotor and in the near wake of the rotor under various wind conditions from cut-in to cut-out.

APPROACH

Smoke generators will be located upstream of the Mod-0 wind turbine at various rotor radii, at the blade tips, and at the blade root ends. Smoke streams, eminating from the generators, will be photographed with high speed cameras placed on the ground in the plane of rotation and either upstream or downstream depending on the ease with which the equipment can be situated. The movies will be analyzed by NASA investigators to determine the flow patterns. The flow patterns will be used by Toledo University and Oregon State University to improve the PROP code and the Vortex Wake Model.

OUTPUT

Slow motion picture films will document the smoke flow patterns for the full operating range of the Mod-0 wind turbine. Three interim reports will be completed to document the flow patterns, using single frame photos from the film, at various operating conditions. The final report will be published in FY 1984.

3.2 Intermediate and Large Systems Technology

Project Title Improvements in PROP and Vortex Wake Codes for Calculating Rotor Performance

Management P. Finnegan (R&TD), 216-433-4000	**CONTRACT NO.** NAG3-278
Contractor Oregon State University Corvallis, OR 97331	***Period of Performance*** 1982 - 1985
	FY 81 Funding $30,000 FY 82 Funding, $50,000
Principal Investigator R. Thresher, 503-754-2535	**CUMULATIVE FUNDING** $80,000
WORK LOCATION Corvalis, Oregon	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

The current methods for predicting rotor performance contain inaccuracies, or do not account for various modes of wind turbine experimental operation.

OBJECTIVE

The objective of this research is to improve the accuracy of methods to predict rotor aerodynamic performance and to more accurately account for performance variations due to additional modes of wind turbine experimental operation.

APPROACH

The data resulting from the aerodynamic research will be utilized, to improve the accuracy of current analytical methods. For example, the data gathered as a result of the research on the rotor blade tip configurations will be used to improve the accuracy of existing methods to predict rotor aerodynamic performance. Both analytical techniques and empirical corrections will be used to improve the accuracy and to account for additional modes of wind turbine experimental operation.

OUTPUT

Two final reports on the Toledo University Vortex Wake model will be available: one in 2Q FY 1983 and the other in 3Q FY 1983. A report on effect C_L and C_D on rotor performance will be available in 3Q FY 1983. The OSU study to improve PROP will be ready in 1Q FY 1985.

3.2 Intermediate and Large Systems Technology

Project Title

Wind Turbine Structrual Design and Analysis

Management D. A. Spera (216)-433-4000	**CONTRACT NO.** NAG 3-87
Contractor Oregon State University Mechanical Engineering Department Corvallis, OR 97331	***Period of Performance*** June 1980 - June 1983
	FY 81 Funding $42,732 FY 82 Funding $43,000
Principal Investigator R. Thresher (503) 754-2535	**CUMULATIVE FUNDING** $85,732
WORK LOCATION Corvallis, OR	**CONTRACTING OFFICE** NASA Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

The technology of large wind turbine systems has advanced rapidly, with contributions from a wide variety of organizations. However, comprehensive structural design criteria have not yet been published.

OBJECTIVE

State-of-the-art structural design technology is to be reviewed, interpreted, and developed into design criteria and methods. Of primary importance is the prediction of dynamic loads and the response of the wind turbine system to these loads.

APPROACH

National workshops on wind turbine technology will be held to compile state-of-the-art design methods and results. Research will be conducted to integrate wind turbulence modeling with rotor blade structural dynamics models for the purpose of developing an analytical model for designers.

OUTPUT

The technical programs of two national workshops have been managed under this grant and proceedings have been edited and published, as follows:

"Wind Turbine Dynamics", Feberuary 24-26, 1981, and "Large Horizontal Axis Wind Turbines", July 28-30, 1982.

3.2 Intermediate and Large Systems Technology

Project Title

Improvements for Wind Turbine Dynamic Analysis Tools

Management Dave Spera (216) 433-4000	**CONTRACT NO.** DEN3-247
Contractor Paragon Pacific, Inc. 1601 East El Segundo Blvd. El Segundo, CA 90245	***Period of Performance*** July 1981 - August 1983
	FY 81 Funding $0 FY 82 Funding $114,542
Principal Investigator J. Hoffman, 213-322-9111	**CUMULATIVE FUNDING** $114,542
WORK LOCATION El Segundo, CA	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

Paragon Pacific, Inc. has developed a series of digital computer programs, called MOSTAS, used by the NASA Wind Energy Project Office for wind turbine aero-structural dynamic analysis and a hybrid analog/digital simulator, called WEST, for wind turbine dynamic behavior. As new technology is identified and deficiencies are found in the current analysis tools, the wind turbine design analysis tools must be continually updated and corrected.

OBJECTIVE

To correct deficiencies and update current wind turbine design analysis tools.

APPROACH

Paragraon Pacific, Inc. will modify the MOSTAS software to improve accuracy or efficiency and correct deficiencies as they become known through continued use of the computer program. PPI will improve the WEST simulator by including additional blade and rotor degrees of freedom, a tower model, and a power train model.

OUTPUT

Changes to the MOSTAS software and documentation will be delivered. An upgraded improved version of the WEST simulator and documentation will be delivered. A report on the results of the WEST verification tests will be written.

3.2 Intermediate and Large Systems Technology

Project Title

Automatic System Test and Calibration Equipment

Management	**CONTRACT NO.**
David C. Janetzke (216) 433-4000	DEN3-203
Contractor	***Period of Performance***
Paragon Pacific, Inc. 1601 East El Segundo Boulevard El Segundo, CA 90245	1980 - 1981 ***FY 81 Funding*** $96,000 FY 82 Funding $0
Principal Investigator	**CUMULATIVE FUNDING**
R. Thoren (213) 322-9111	$96,000
WORK LOCATION	**CONTRACTING OFFICE**
El Segundo, CA	NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

Paragon Pacific, Inc. has developed a hybrid analog/digital simulator, called WEST, for wind turbine dynamic behavior. To maintain accuracy of the system, the numerous electronic components must be regularly checked for failure and calibration.

OBJECTIVE

To replace the tedious and time-consuming procedure for maintaining accuracy on the WEST, an automatic checkout system is required.

APPROACH

Paragon Pacific, Inc. will design, build, test, and deliver an Automatic System Test and Calibration (ASTAC) unit for the WEST simulator.

OUTPUT

One ASTAC unit will be delivered with supporting documentation of its design and use. A final report, NASA CR-165403, was published which describes the system in moderate detail.

3.2 Intermediate and Large Systems Technology

Project Title

Analytical Support Services

Management	**CONTRACT NO.**
D. Spera (216) 433-4000	DEN3-79
Contractor	***Period of Performance***
Paragon Pacific, Inc. 1601 East El Segundo Boulevard El Segundo, CA 90245	1979-1981
	FY 81 Funding $15,000 FY 82 Funding -0-
Principal Investigator	**CUMULATIVE FUNDING**
J. Hoffman (213) 322-9111	$44,981
WORK LOCATION	**CONTRACTING OFFICE**
El Segundo, CA	NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

Paragon Pacific, Inc. developed the primary aero-structural dynamic codes used by the NASA Wind Energy Project Office. Rapid increase in the type and number of wind turbine designs to be analyzed requires analytical support services in order to meet development schedules.

OBJECTIVE

Paragon Pacific, Inc. will provide maintenance services on computer programs, update the codes and user manuals, and develop an analog/digital simulator for the dynamic characteristics of a wind turbine. Other calculation services will be procured as required.

APPROACH

Paragon Pacific personnel will develop math models and write special purpose computer codes as required by the NASA Wind Energy Project Office.

OUTPUT

Updated coding for the MOSTAS structural dynamics analysis code and the WEST simulator were produced and delivered to NASA with supporting documentation.

3.2 Intermediate and Large Systems Technology

Project Title Control, Synchronization, Switchgear, and Protective Relaying of Large Wind Turbine Generators Connected to Utility Networks

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** DEN3-252
Contractor Power Technologies, Inc. 1482 Erie Boulevard Schenectady, NY 12301	***Period of Performance*** 1981-1983 ***FY 81 Funding*** $63,000 FY 82 Funding $0
Principal Investigator E. N. Hinrichsen (518) 374-1220	**CUMULATIVE FUNDING** $63,000
WORK LOCATION Schenectady, NY	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

During the past two years Power Technologies, Inc. has conducted two studies of the dynamics of single and multiple wind turbine generators connected to utility networks. As a result, several areas of technology that warrant further investigation were identified. One of these areas included speed and/or power control of wind turbines.

OBJECTIVE

Determine the implications and the advantages and disadvantages of basing the primary control of wind turbines on the rotor speed and using a secondary, slower acting, reset type power control superimposed on the speed control.

APPROACH

This engineering effort will be an analysis taking into consideration the major wind turbine generator design variables which influence the four areas under investigation. Consideration will be given to single speed turbines, multi-speed turbines, continuously variable speed turbines, synchronous generators, and induction generators. Where the results of the study have a significant impact on equipment selection, the relative cost of the various alternatives will be given. A test will be conducted on the Mod-0 to verify the performance of the speed control methods.

OUTPUT

Subsequent to the contractor's study of the effect of speed control versus power control of wind turbines, the contractor was redirected to eliminate the synchronization and switchgear studies originally contemplated. The contractor was requested to prepare a test plan for and participate in testing of speed control applied to the Mod-0 wind turbine. The test plan was submitted to NASA. Speed control tests with the Mod-0 machine are planned for early in 1983.

The contractor has presented two progress reports on the work done and has prepared one technical paper for presentation at the 1983 Winter Meeting of the IEEE. A draft of the final report was submitted to NASA and will be supplemented by the results of tests with the Mod-0 wind turbine.

3.2 Intermediate and Large Systems Technology

Project Title

Low-Cost, Fiberglass TFT, Mod-0A Wind Turbine Blades

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** DEN3-100
Contractor Structural Composite Industries Azusa, CA 91702	***Period of Performance*** 1979-1982
	FY 81 Funding $1,450,000 FY 82 Funding $0
Principal Investigator O. Weingart (714) 594-7777	**CUMULATIVE FUNDING** $1,500,000
WORK LOCATION Azusa, CA	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

This contract was prompted by the need for the development of economical, Mod-0A wind turbine blades. A variety of materials including TFT (transverse filament tape) fiberglass/epoxy using a filament-winding method were examined as potential blade materials. Key problems associated with this study included the design and definition of a manufacturing sequence for a three-cell blade by a filament-winding process, blade weight control, and ability to control and maintain a specified aerodynamic shape during manufacturing.

OBJECTIVE

The objective of this study is to develop and deliver a set of low-cost, Mod-0A TFT fiberglass wind turbine blades, design and deliver blade sections and laboratory-type laminates for fatigue testing.

APPROACH

This contract was one of three studies initiated for the development of low-cost, Mod-0A blades. The blade design effort proceeded from a preliminary to final design sequence with periodic technical reviews. Included in the contract was the design and delivery of a root-end test blade section for fatigue testing, half-scale blade specimens for qualification testing of the flanged root end adapter design, and laminates for the development of a TFT fatigue data base.

OUTPUT

A set of TFT fiberglass blades were installed on the Mod-0A wind turbine at Clayton, NM and successfully tested from August 1981 through June 1982. Results of blade tests and blade section fatigue tests indicate that the design has excellent fatigue-resistance characteristics. All deliverable items on this contract have been received, including the final report NASA CR-165342.

3.2 Intermediate and Large Systems Technology

Project Title

The Yawing of Wind Turbines with Passive Blade Cyclic Pitch

Management SERI Richard L. Mitchell (303) 231-1379	**CONTRACT NO.** XE-1-1052-1
Contractor Washington University Technology Associates 8049 Litzsinger Road Brentwood, Missouri 63144	***Period of Performance*** January 1981 to April 1982 ***FY 81 Funding*** $97,364 FY 82 Funding $4,088
Principal Investigator K.H. Hohenemser (314) 880-6175	**CUMULATIVE FUNDING** $245,944
WORK LOCATION Brentwood, Missouri	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Large wind turbines have all used some combination of yaw drive and dumping to control the large aerodynamic forces and maments due to skewed flows acting on the rotor disk. The use of collective pitch for speed control also precludes the development of pitch control stratagies designed to take advantage of wind shear or other regular atmospheric flow variations. The study of passive cyclic pitch control for yawing and turbine control are currently being pursued.

OBJECTIVE

The objective of this project is to determine the potential for wind energy conversion using a horizontal axis rotor with passive cyclic pitch variation.

APPROACH

The yaw control system characteristics of a small scale wind rotor using passive blade cyclic pitch were determined by wind tunnel and field testing and analyses. The yaw characteristics, power output, and loads were determined for a specific HAWT test model. The analytical results were verified with the testing of a free atmospheric testing of a small scale machine. Further field tests incorporating automatic furling and yaw control are to be conducted.

OUTPUT

A final report is to be submitted by the subcontractor detailing the test and analysis results.

- SERI/TP-11052-1, December 1981
- SERI/TP-98085-3, December 1980

3.2 Intermediate and Large Systems Technology

Project Title	Measurements of Lift and Drag Coefficients of Existing Airfoils in High Stall Condition for Infinite and Finite Aspect Ratios
Management P. Finnegan (R&TD) (216) 433-4000	**CONTRACT NO.** NSG-3277
Contractor Wichita State University Wichita, Kansas	***Period of Performance*** 1982 to 1984
	FY 81 Funding $60,000 — FY 82 Funding $40,000
Principal Investigator M. H. Snyder (316) 689-3410	**CUMULATIVE FUNDING** $100,000
WORK LOCATION Wichita, Kansas	**CONTRACTING OFFICE** NASA-Lewis Research Center, Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

Fixed pitch rotors operating in high winds, for both large and small machines, have been found experimentally to produce higher peak and post peak power than is predicted by the rotor performance codes. These rotor blades operate in a stalled condition. To make accurate performance predictions accurate lift and drag coefficients (C_L and C_D) data are needed in the stalled or high angles of attack. Such C_L and C_D data exists only for thin symmetrical airfoils and this data is normally substituted in the absence of more accurate data.

OBJECTIVE

Determine the C_L and C_D data for selected existing rotor blade airfoils at angles of attack up to 180 degrees and to determine the effect of blade aspect ratios on these quantities.

APPROACH

Both two dimensional and three dimensional models will be fabricated of NACA airfoils such as the 23024, 64_3-618 and others. These models will be tested in a wind tunnel. Measurements will be made of the lift and drag forces, and surface pressure distributions. This data will be processed to determine the C_L and C_D. The three dimensional data finite aspect ratios will be compared with the two dimensional data to determine the effect of aspect ratio. The two dimensional C_L and C_D data, infinite aspect ratio, will also be compared with theoretically calculated values. Also, the effect of airfoil parameters such as the leading edge radius, thickness, and surface roughness on the C_L and C_D under stalled conditions will be investigated.

OUTPUT

The measured two dimmensional C_L and C_D data will be reported in 4Q FY 1983. A report on the influence of aspect ratio will be completed in 1Q FY 1984. A report on the effect of the airfoil characteristics on the C_L and C_D under stalled conditions will be completed during the 1Q FY 1985.

3.2 Intermediate and Large Systems Technology

Project Title

Studies of Spoiler and Aileron Control Systems for Large Scale Wind Turbines

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** Grant NSG-3277
Contractor Wichita State University College of Engineering Wind Energy Laboratory Wichita, KS 67208	***Period of Performance*** 1979-1983 ***FY 81 Funding*** $99,300 FY 82 Funding $155,800
Principal Investigator W. Wentz (316) 689-3410	**CUMULATIVE FUNDING** $350,800
WORK LOCATION Wichita, KS; Cleveland, OH	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

Pitch control systems are normally required to perform three functions - startup, shutdown, and rpm and power control. Spoilers and flap controls can control rpm and power and can shut down the WT. The controls do not work as well for WT startup control but this may not be important if yaw or motor startup are used.

OBJECTIVE

The objective of this project is to evaluate the performance of a rotor with an aileron control surface.

APPROACH

The approach is for Wichita State University to provide technical support for the analysis, design, and fabrication of the aileron; then monitor the full scale test of the aileron; and finally to report the results of the test.

OUTPUT

Fabrication of the aileron-controlled rotor tip was completed in FY 82. Structural ground verification tests were completed in July 1982. The test results indicated that the aileron-control tip structure is adequate to carry the predicted emergency shutdown loads. The two aileron blade tips will be installed on the Mod-0 wind turbine in FY 83. A final report published in FY 1983 will detail the performance of this 20 percent chord aileron located on the outer 30 percent of the blade span.

3.2 Intermediate and Large Systems Technology

Project Title

Fatigue Testing of Wood Composite Wind Turbine Blade Materials

Management P. Finnegan (216) 433-4000	**CONTRACT NO.** DEN3-286
Contractor University of Dayton Research Institute Dayton, OH 45469	***Period of Performance*** 1982-1983
	FY 81 Funding $0 FY 82 Funding $74,500
Principal Investigator G. Roth (513) 229-3812	**CUMULATIVE FUNDING** $74,500
WORK LOCATION Dayton, OH	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, OH

PROJECT SUMMARY

BACKGROUND

The feasibility has been established for fabricating low-cost, large diameter wind turbine blades from epoxy resin-bonded Douglas fir veneers. However, the fatigue strength allowables are based on tests conducted in 1944 on solid dimensional lumber stressed in flexure. Based on these data, a conservative approach must be taken resulting in blade designs heavier than necessary.

OBJECTIVE

The objective of this research is to develop and up-to-date and comprehensive material property data base for epoxy resin-bonded Douglas fir laminates for application to the design of future large diameter wood composite wind turbine rotors.

APPROACH

The first phase of this program will involve the development of an optimum specimen geometry and gripping method for static and fatigue testing. After the development of a satisfactory specimen geometry and gripping method have been completed, static and fatigue data will be generated. Test variables include wood grade, moisture content, butt joint gap, test temperature and environmental humidity levels. The primary data base will be established using grade A veneers at 6% moisture content and at a room temperature 50% relative humidity environment. The effect of other variables such as elevated temperature and humidity, veneer grades (A+ and C) will be spot checked.

OUTPUT

A final report will be published and will contain all of the test data in a form suitable for the establishment of stress allowables for the design of wood composite wind turbine blade structures.

3.3 Evolving Technologies

Project Title

TESTS AND DEVICES FOR WIND/ELECTRIC POWER CHARGED AEROSOL GENERATOR

Management SERI (303) 231-1379 Richard L. Mitchell	**CONTRACT NO.** XH-9-8128-1
Contractor Marks Polarized Corp. 153-16 Tenth Ave. Whitestone, NY 11357	***Period of Performance*** July 1976 - July 1980
	FY 81 Funding FY82 Funding Carry over FY1979 funding
Principal Investigator (212) 767-9600 Alvin M. Marks	**CUMULATIVE FUNDING** $263,255
WORK LOCATION Whitestone, NY	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Under previous Department of Energy, Energy Research and Development Administration, and National Science Foundation funding, a wind tunnel test facility was developed, methods were identified and evaluated, and tests conducted on four methods of electofluid dynamic (EFD) aerosol charging. Resulting data demonstrated the feasibility and potential of one of these methods. The key technical problem that remains is to develop this method for efficiently charging the aerosol.

OBJECTIVE

The objectives of this effort were to investigate, experimentally, the induction charging (waterjet method for an EFD machine) and to compare the results with existing theories.

APPROACH

The research approach includes the design and manufacture of specific orifices and the performance of parametric tests using the induction charging/waterjet method. The environmental test data on these devices included variation in velocity, air temperature and relative humidity. The results of the testing established the optimum orifice sizes and performance.

OUTPUT

Experimental equipment and orifices were designed and constructed and experimental data was obtained on the critical parameters and constraints of the induction charging/waterjet technique.

3.3 Evolving Technologies

Project Title

Aerodynamics: Natural Laminar Flow Blade Elements

Management Sandia National Laboratories	**CONTRACT NO.** 40-3970
Contractor Ohio State University Aeronautical and Astronautical Dept. 2070 Neil Avenue Columbus, OH 43210	***Period of Performance*** October 1980-September 1982
	FY 81 Funding FY82 Funding $10,000 $4,494
Principal Investigator G. M. Gregorek -- 614-940-2198	**CUMULATIVE FUNDING** THROUGH FY82 $14,494
WORK LOCATION Columbus, OH	**CONTRACTING OFFICE** Sandia Natl. Labs., Albuquerque, NM

PROJECT SUMMARY

BACKGROUND

The operating environment of a Darrieus VAWT blade element is very different from those of airfoils in most other aeronautical applications. Unsteady aerodynamics, relatively low Reynolds numbers, wide ranges over both positive and negative angles-of-attack, and late- and post-stall operation are some of the differentiating features.

OBJECTIVE

To design airfoil geometries specifically for the Darrieus VAWT application using principles of laminar flow aerodynamics.

APPROACH

- Given a set of desired airfoil characteristics and VAWT flowfield speeds and angles, calculate a number of profile geometries with performance characteristics approaching the goals.
- Using calculated section characteristics and turbine aerodynamic performance/load codes, screen the candidate sections.
- Extrude and test one or more candidates on the SNL 5 meter research turbine.

OUTPUT

Definition of natural laminar flow airfoils designed to enhance performance and reliability of a Darrieus VAWT in the DOE 100 kW class.

3.3 Evolving Technologies

Project Title

Aerodynamic Performance Tailoring of the VAWT

Management Sandia National Laboratories	**CONTRACT NO.** S68-4856 and SNL 37-0010
Contractor Oregon State University P.O. Box 1086 Corvallis, OR 97330	***Period of Performance*** October 1980-August 1983
	FY 81 Funding $34,624 — FY82 Funding $31,560
Principal Investigator R. E. Wilson -- 503-754-2218	**CUMULATIVE FUNDING** THROUGH FY82 $96,183
WORK LOCATION Corvallis, OR	**CONTRACTING OFFICE** Sandia Natl. Labs., Albuquerque, NM

PROJECT SUMMARY

BACKGROUND

Current Darrieus VAWT airfoils are not optimum from the reliability or performance points of view. The characteristics are functions of a large number of parameters and are generally not able to be quantified in a cost-effective way.

OBJECTIVE - The objective of analyzing aerodynamics for the Darrieus VAWT is to tailor the efficiency between the coefficient of power $(C_p)_{max}$ and $(C_p/\lambda^3)_{max}$ for improved reliability and economics using passive rotor schemes.

APPROACH

The principal tool used in assessing aerodynamic performance is the fixed wake hybrid vortex/momentum model developed by the investigators. This study considers the effects of blade camber, offset, and dynamic stall.

OUTPUT

Report: R. E. Wilson, S. N. Walker, Oregon State University, "Fixed Wake Analysis of the Darrieus Rotor," Sandia National Laboratories Report, SAND81-7026, July 1981.

3.3 Evolving Technologies

Project Title

VORTEX AUGMENTORS FOR WIND ENERGY CONVERSION

Management SERI (303) 231-1379 Richard L. Mitchell	**CONTRACT NO.** ET-77-C-01-2358
Contractor Polytechnic Institute of New York Route 110 Farmington, NY 11735	***Period of Performance*** May 1976 - August 1979 ***FY 81 Funding*** FY82 Funding Carry over FY1976 funding
Principal Investigator (516) 694-5500 Pasquale M. Sforza	**CUMULATIVE FUNDING** $379,927
WORK LOCATION Farmington, NY	**CONTRACTING OFFICE** DOE Wind Systems Branch

PROJECT SUMMARY

BACKGROUND

Appropriate interaction of properly designed aerodynamic surfaces with natural wind of low power density can generate discrete vortical flow of relatively high power density. Suitable turbines may then be used to extract the energy from this compacted vortical field. This idea for energy concentration in natural flows is termed the Vortex Augmentor Concept(VAC).

OBJECTIVE

The objective of this project is to determine the technical feasibility, performance, and potential of the delta wing VAC for wind energy conversion.

APPROACH

The VAC field test protype instrumentation was refined to provide detailed information on torque, speed, and power output under actual field conditions. Stability, control, and saftey aspects of the prototypeVAC system were determined under power generation. Performance maps, power control flaps, and additional laboratory testing were conducted.

OUTPUT

Results of the field tests and other studies were utilized to determine the potential of the vortex augmentor concept for implementation.

Project Title

Analytical Modeling

Management R. H. Braasch -- 505-844-3850	**CONTRACT NO.** DE-AC04-76DP00789
Contractor Sandia National Laboratories	***Period of Performance*** Ongoing
	FY 81 Funding $780,000 — FY82 Funding $900,000
Principal Investigator P. C. Klimas -- 505-844-8159 W. N. Sullivan -- 505-844-7357	**CUMULATIVE FUNDING** THROUGH FY82 $2,600,000
WORK LOCATION Albuquerque, NM	**CONTRACTING OFFICE** Sandia National Laboratories

PROJECT SUMMARY

BACKGROUND

In mid-1975, Sandia National Laboratories, Albuquerque (SNLA) was tasked to determine the technical and economic feasibility of the Darrieus VAWT design. Having accomplished this task in FY79, efforts have progressed in developing the technology base through analytical modeling verified through research testing.

OBJECTIVE

The analytical modeling program is formulated to provide the advanced technology needed to stimulate industrial involvement in VAWT design leading to sustained participation by industry.

APPROACH

To develop models that take into account all important phenomena that accurately characterize the performance, loads, and structural response of Darrieus VAWT systems.

OUTPUT

Verified analytic models usable by SNL and industry that can be used to design viable and reliable VAWT systems.

3.3 Evolving Technologies

Project Title

Systems Engineering

Management R. H. Braasch -- 505-844-3850	**CONTRACT NO.** DE-AC04-76DP00789
Contractor Sandia National Laboratories	***Period of Performance*** Ongoing
	FY 81 Funding $250,000 — FY82 Funding $350,000
Principal Investigator E. G. Kadlec -- 505-844-8669	**CUMULATIVE FUNDING** THROUGH FY82 $800,000
WORK LOCATION Albuquerque, NM	**CONTRACTING OFFICE** Sandia National Laboratories

PROJECT SUMMARY

BACKGROUND

Under DOE sponsorship, the first sizeable (17 meter) Darrieus VAWT was designed and built as a research system. This system has been operational since 1977. As a follow-on, the DOE 100 kW system was designed and fabricated under contract by Alcoa. Three of these first-generation systems have been operated since 1980/81.

OBJECTIVE

The objective is to incorporate the latest technology in system design philosophy and designs to produce designs that are cost-effective and will be incorporated by industry.

APPROACH

1. Work with industry through the "VAWT Data Base and Verification" Program (COVAWT) to upgrade VAWT designs.
2. Continually develop design philosophies that improve VAWT performance, cost-effectiveness, and reliability. Incorporate these design philosophies into an advanced system test bed design.

OUTPUT

Structural loads data and model verification through cooperative testing of industry-owned and operated machines.

3.3 Evolving Technologies

Project Title

Aerodynamic Performance Tailoring (C_p Tailoring)

Management	**CONTRACT NO.**	
R. H. Braasch -- 505-844-3850	DE-AC04-76DP00789	
Contractor	***Period of Performance***	
Sandia National Laboratories	Ongoing	
	FY 81 Funding	FY82 Funding
	$100,000	$130,000
Principal Investigator	**CUMULATIVE FUNDING**	THROUGH FY82
P. C. Klimas -- 505-844-8159 E. G. Kadlec -- 505-844-8669	$230,000	
WORK LOCATION	**CONTRACTING OFFICE**	
Albuquerque, NM	Sandia National Laboratories	

PROJECT SUMMARY

BACKGROUND

At the onset of the Darrieus VAWT program, the best known of the available airfoils (NACA 00XX) were chosen. While these airfoils performed well, certain deficiencies were noted, i.e., stall regulation at high power levels, relatively low turbine rotational speed.

OBJECTIVE

The objective of C_p tailoring is to develop airfoils and techniques to enhance aerodynamic performance, system reliability, and cost effectiveness.

APPROACH

Study and test laminar flow airfoils, cambered airfoils, and induced stall concepts (using blown spoiling) on the 5 meter research machine and the 17 meter research machine. Confirm effect on systems performance using systems models. This effort combines the outputs of Texas Tech, Oregon State University, Ohio State University, and Sandia National Laboratories.

OUTPUT

Airfoils and techniques to improve aerodynamic performance, systems reliability, and cost effectiveness.

3.3 Evolving Technologies

Project Title

Aerodynamics: Dynamic Stall Regulation of the Darrieus Turbine

Management Sandia National Laboratories	**CONTRACT NO.** SNL 74-1218 (09725 Case 0518.300 7/25/80)
Contractor Texas Tech University Office of Research Services Box 4670 Lubbock, TX 79409	***Period of Performance*** July 1980-January 1983
	FY 81 Funding $59,847 — FY82 Funding $38,900
Principal Investigator J. W. Oler -- 806-742-3563	**CUMULATIVE FUNDING** THROUGH FY82 Total Contract Price: $98,747
WORK LOCATION Lubbock, TX	**CONTRACTING OFFICE** Sandia National Laboratories

PROJECT SUMMARY

BACKGROUND - Aerodynamic stall is the mechanism which provides the power regulation of Darrieus VAWTs and is therefore of essential interest. Stall behavior of a section in an unsteady flowfield, such as that seen by a Darrieus blade element, has been shown to be significantly different than that of the same section in a static environment. Currently, only limited experimental information and low confidence semi-empirical predictive schemes are available for quantifying these important dynamic stall effects.

OBJECTIVE
The proposed research effort will be aimed at upgrading the present aerodynamic prediction capability such that arbitrary changes in airfoil geometry can be evaluated with respect to performance and blade loading.

APPROACH - The following is a list of efforts which will be conducted during the course of this work:
- Develop a state-of-the-art unsteady aerodynamic airfoil model to be used to upgrade the VDART2 and double multiple streamtube computer codes.
- Verify the accuracy of the airfoil model using existing static and oscillating airfoil data.
- Verify the accuracy of the upgraded model using experimental data from tow tank model rotor tests.
- Demonstrate the capability of the model to predict benefits to be gained from careful selection of airfoil sections based on dynamic characteristics.
- Demonstrate the capability of the model to evaluate innovative design concepts, such as "porous airfoils."

OUTPUT - The final report will include a description of the mathematical model, a listing of the computer code implementing the model, and a comparison of predicted and measured dynamic stall section characteristics.

3.3 Evolving Technologies

Project Title

OSCILLATING VANE CONCEPT

Management SERI Richard L.Mitchell (303) 231-1379	**CONTRACT NO.** XH-9-8085-2
Contractor United Technologies Research Center Silver Lane East Hartford, CT 06108	***Period of Performance*** September 1979 - October 1981
	FY 81 Funding FY82 Funding Carry over FY1979 funding
Principal Investigator R.L. Bielawa (203) 727-7154	**CUMULATIVE FUNDING** $119,900
WORK LOCATION East Hartford, CT	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

This Concept employs the flutter principal as its energy conversion mechanism. The concept may have material advantages over turbine type concepts due to a simplification of the aerodynamic element and a reduction in support structure requirements.

OBJECTIVE

The objective of this project is to evaluate the feasibility of the Oscillating Vane concept as applied to wind energy conversion.

APPROACH

A four foot wind tunnel model was designed, constructed, and tested to establish the technical performance and potential of the concept.

OUTPUT

A final report was submitted by the subcontractor detailing the concept, test results, the analysis methods used, and the results of the testing and analysis of the concept.

- SERI/TP-98085-2, December 1980

3.3 Evolving Technologies

Project Title

Proof-of-Concept Testing of the Passive Cyclic Pitch Concept

Management Richard L. Mitchell (SERI) (303)231-1379	**CONTRACT NO.** XE-2-2054-1 XE-2-2134-1
Contractor Washington University School of Engineering & Applied Science St. Louis, MO 63130	***Period of Performance*** March 15, 1982 to March 31, 1983 ***FY 81 Funding*** FY82 Funding -0- $42,397
Principal Investigator K.H. Hohenemser (314)889-6057	**CUMULATIVE FUNDING** $42,397
WORK LOCATION Washington University	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Under previous SERI subcontracts Washington University Technology Associates established the passive cyclic pitch concept as having a significant potential in WECS load reduction. A proof-of-concept test was required to verify this prediction.

OBJECTIVE

The objective of this project is to design, construct and deliver to the Rocky Flats test center an 8kW Passive Cyclic Pitch proof-of-concept model.

APPROACH

The model was designed and constructed under a lower tier subcontract. The proof-of-concept machine was then delivered to the Rocky Flats Small Wind Systems test center. The test center is to conduct field testing of the model.

OUTPUT

The Proof-of-Concept model was constructed and the data and analysis results from the field testing are to be presented in a final report.

3.4 Innovative Concepts

Project Title

THE GYROTURBINE TETHERED WIND ENERGY SYSTEM ASSESSMENT

Management SERI (303) 231-1379 Richard L. Mitchell	**CONTRACT NO.** XE-0-9172-1
Contractor Aerospace Systems, Inc. 121 Middlesex Turnpike Burlington, MA 01803	***Period of Performance*** September 1980 - March 1982
	FY 81 Funding FY82 Funding Carry over FY1980 funding
Principal Investigator R. Noll (617) 272-7517	**CUMULATIVE FUNDING** $36,950
WORK LOCATION Burlington, MA	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The increased energy density in the wind at higher altitudes offers a potential for increased technical performance for wind turbines which are tethered at these higher altitudes (including the possibility of the jet stream). The GyroTurbine is a Tethered Wind Energy System which holds some technical potential. Operating in a helicopter mode during deployment and banking into the wind for a combination of power generation and lifting forces, the concept allows for a simple configuration.

OBJECTIVE

The objective of this project is to provide a detailed assessment of the technical potential of the GyroTurbine Tethered Wind Energy System, including the technical characteristics and performance.

APPROACH

Overall systems studies were conducted to size the GyroTurbine and associated systems, and trade-off studies were carried out on the power generation, tethering and transmission cable, and associated components. An assessment of the technical potential and performance of the concept was conducted.

OUTPUT

The subcontractor will provide a final report containing a detailed assessment of the Tethered GyroTurbine concept, and an evaluation of it's technical potential.

- SERI/TP-09172-1

3.4 Innovative Concepts

Project Title

THE FLEXROTOR WIND ENERGY INNOVATIVE SYSTEMS ASSESSMENT

Management SERI (303) 231-1379 Richard L. Mitchell	**CONTRACT NO.** XE-0-9173-2
Contractor Aerospace Systems, Inc. 121 Middlesex Turnpike Burlington, MA 01803	***Period of Performance*** September 1980 - March 1982
	FY 81 Funding FY82 Funding Carry over FY1980 Funding
Principal Investigator J. Zvara (617) 272-7517	**CUMULATIVE FUNDING** $33,875
WORK LOCATION Burlington, MA	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The use of cables as support or tension straps for the blades and struts of a straight bladed vertical axis wind turbine has the potential of reducing the materials of construction required below that of a similar turbine. The use of these tension straps would reduce the engineering requirements but would, due to the blade softness, also change the machine performance with modified angles of attack.

OBJECTIVE

The objective of this project is to provide a critical assessment of the technical characteristics and performance of the FlexRotor Wind Energy concept.

APPROACH

The effort will conduct an overall design study adressing the aerodynamic and mechanical requirements of the FlexRotor and establishing an optimum design configuration and size. The system performance and technical characteristics of the concepts are to be evaluated.

OUTPUT

The subcontractor will provide a final report containing the details of the design study and a discussion of the technical characteristics and potential of the FlexRotor Wind Energy Innovative System.

- SERI/TP-09173-2, November 1981

3.4 Innovative Concepts

Project Title

Dynamic Inducer

Management	**CONTRACT NO.**
Richard L. Mitchell (SERI) (303)231-1379	SE-1-1167-1
Contractor	***Period of Performance***
AeroVironment, Inc. 145 Vista Ave. Pasadena, CA 91107	July 1981 - June 1982
	FY 81 Funding FY82 Funding
	$110,650 $37,978
Principal Investigator	**CUMULATIVE FUNDING**
Andy Zalay (213) 499-4392	$281,463
WORK LOCATION	**CONTRACTING OFFICE**
Pasadena, California	Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Dynamic Induction involves the use of additional lifting surfaces, inducer vanes, attached to the power blades of a wind turbine, which by their motion dynamically induce additional flow through the power blade disk. This provides additional energy flow which may be absorbed by the power blades.

OBJECTIVE

The objective of this project is to determine the performance and the technical potential of the tip vane power augmentation on wind and water tunnel models and on an actual four meter diameter wind turbine operating in the field.

APPROACH

The optimal tip vane geometry with wind tunnel testing using power blades was determined. The power output and torque for the dynamic inducer with power blades was established in the wind tunnel and field tests were conducted. An analysis of the performance and technical potential of the Dynamic Inducer was conducted. Optimization of tip vane and power blade configurations is being carried out with water tunnel models.

OUTPUT

Final reports were submitted by the subcontractor, detailing the concept, test results, the analysis methods used, and the results of the testing and analyses of the system.

- SERI/TR-98085-1, May 1981
- SERI/TR-11167-1, May 1982

3.4 Innovative Concepts

Project Title

Production Costing of an Innovative WECS

Management Eric W.Jacobs (SERI) (303)231-1171	**CONTRACT NO.** BE-9-8282-20
Contractor CACI, Inc. - Federal 1815 N. Fort Myer Drive Arlington, VA 22209	***Period of Performance*** July 10, 1980 to February 28, 1982
	FY 81 Funding FY82 Funding $89,500 -0-
Principal Investigator John C. Callahan (703)841-7800	**CUMULATIVE FUNDING** $89,500
WORK LOCATION CACI, Inc. - Federal	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

A consistent and objective method for calculating the cost of energy that will be produced by an Advanced/Innovative Wind Energy Concept (AIWEC) is required in order to guage the potential of that AIWEC. To do this a computerized costing methodology such as the Solar Array Manufacturing Industry Costing Standards (SAMICS) is necessary. SAMICS was developed for costing photovoltaic arrays but is sufficiently general to cost most any product and has previously been used, for example, to cost heliostats.

OBJECTIVE

To adapt the SAMICS methodology for use in the production costing of AIWEC.

APPROACH

The subcontractor shall take the specs of an AIWEC provided by SERI and develop a process sequence for manufacturing it. The subcontractor shall then adapt and utilize the SAMICS methodology to provide cost estimates for the given AIWEC. The adapted SAMICS methodology can then be used by SERI for costing other AIWEC.

OUTPUT

A final report describing the SAMICS adaptation and the costing results for the chosen AIWEC entitled "Production Costing of an Advanced/Innovative Wind Energy Concept (AIWEC): Extension of the SAMICS Methodology, "SERI/TR-98282 - 2, November 1982

3.4 Innovative Concepts

Project Title

Wind-Driven Heat Pump Application to Building Heating

Management USDA-ARS R. N. Clark (806) 378-5721	**CONTRACT NO.** DE-AI01-76ET20319
Contractor Cornell University Agricultural Engineering Department	***Period of Performance*** 2 years
	FY 81 Funding $116,000 — FY 82 Funding $5,000
Principal Investigator W. W. Gunkel (607)256-2297	**CUMULATIVE FUNDING** $121,000
WORK LOCATION Ithaca, NY	**CONTRACTING OFFICE** USDA-ARS, Conservation and Production Research Laboratory, Bushland, TX

PROJECT SUMMARY

BACKGROUND By converting wind energy to heat by means of a heat pump, the heat energy output of a wind system may be substantially increased by the coefficient of performance (COP) of the heat pump. In a large area of fair to good wind regimes, the expected (COP) can be two or more, effectively doubling the energy capture of a wind system for heating if satisfactory operation of a heat pump may be obtained with the variable output of SWEC's.

OBJECTIVE To determine the methods and operating parameters for driving a heat pump with either mechanical or electrical interfaces for building heating.

APPROACH A cooperative agreement will be entered into with a university having proper faculty and facilities to pursue the research objectives of determining methods and parameters for interfacing a heat pump with the variable speed and/or power of a wind system. Both laboratory and field studies will be conducted to determine and verify the approaches developed.

OUTPUT

1. Report of research and evaluation of wind operated heat pump
2. Design concepts and parameters for SWEC's/heat pump interface

3.4 Innovative Concepts

Project Title

Further Investigations of the Diffuser Augmented Wind Turbine

Management Richard Mitchell (SERI)(303)231-1379	**CONTRACT NO.** XE-1-01311-1
Contractor Grumman Aerospace Corp. South Oyster Bay Road Bethpage, NY 11714	***Period of Performance*** June 1975-December 1982
	FY 81 Funding Carryover 1979 funding FY82 Funding $148,000
Principal Investigator K.M. Foreman (516)575-2221	**CUMULATIVE FUNDING** $705,224.00
WORK LOCATION Bethpage, New York	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

A diffuser creates a low subatmospheric pressure behind a turbine rotor. A consequence of this suction is the capture of significantly more wind through a diffuser augmented wind turbine (DAWT) than a conventional wind turbine. The resulting increase mass flow increases the output power and has the potential for increased technical performance.

OBJECTIVE

The objective of this project was to refine the performance and engineering design of a compact diffuser in order to improve confidence in scaled up designs and the technical potential of full scale DAWT systems. These designs are then to be tested in a wind tunnel to verify the performance predictions.

APPROACH

This project employs wind tunnel testing, engineering design and producibility analyses to increase the relative power coefficient of the concept and to estimate the requirements for the construction of a field demonstration unit.

OUTPUT

Wind tunnel tests have provided performance data which are extrapolated to full scale field test conditions. Manufacturing estimates were obtained for a prototype engineering design of a candidate diffuser configuration. A meaningful field demonstration model was sized. The results of this effort are to be presented in final reports.

- SERI/TR-98073-1B, December 1981

3.4 Innovative Concepts

Project Title

TORNADO-TYPE WIND ENERGY SYSTEMS (Phase II)

Management SERI (303) 231-1379 Richard L. Mitchell	**CONTRACT NO.** EX-76-C-01-2555
Contractor Grumman Aerospace Corp. South Oyster Bay Rd. Bethpage, NY 11714	***Period of Performance*** March 1979 - June 1980
	FY 81 Funding FY82 Funding Carry over FY1978 funding
Principal Investigator James T. Yen (516) 575-2221	**CUMULATIVE FUNDING** $434,731
WORK LOCATION Bethpage, NY	**CONTRACTING OFFICE** DOE Wind Systems Branch

PROJECT SUMMARY

BACKGROUND

This concept incorporates a tall cylindrical tower with an open top, slotted side openings with guide vanes to create swirling, tornado-like vortex in the tower. Outside air enters the base of the tower and is drawn upward through the rotor at the bottom of the tower causing the rotor blades to spin and drive the generator.

OBJECTIVE

The major objective of this project is to determine the practicality and technical potential of the Tornado-Type Wind Energy System (TTWES) through wind tunnel testing and aerodynamic and engineering analyses.

APPROACH

Both theoretical and experimental investigations were carried out. A multi-vaned tower model of up to six feet in height was made and tested. Turbines of up to one foot in diameter were designed, manufactured and installed in the model. Small high speed models of up to one foot in diameter with a four inch diameter turbine were designed, constructed and tested. An eighteen foot high, six foot diameter model was designed and constructed.

OUTPUT

Data and analyses from wind tunnel tests provided a better understanding of the technical potential of the TTWES. Detailed information regarding the inlet-vane design, scaling estimates, and overall potential were obtained. Comparisons were made between the spiral and multi-vane towers, and all results were presented in a final report.

- SERI/TR-11052-1, May 1980

3.4 Innovative Concepts

Project Title

Airfoil Configuration

Management Richard L. Mitchell (SERI) (303)231-1379	**CONTRACT NO.** AE-1-1045-1
Contractor Melior Corp. 712 5th Street, Suite B Davis, CA 95616	***Period of Performance*** February 21, 1981 to July 31, 1981
	FY 81 Funding FY82 Funding $6,438 -0-
Principal Investigator P.G. Migliore (916)756-5522	**CUMULATIVE FUNDING** $6,438
WORK LOCATION Davis, California	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Previous research on VAWT airfoil performance by West Virginia University and Melior Corp.. under DOE contract has identified three major phenomena affecting force coefficients. These phenomena (virtual aerodynamics, boundary layer centrifugal effects, and trailing edge radius of curvature) should be studied in order to provide insight into their potential for improvement of VAWT performance.

OBJECTIVE

The objective of this project was to identify promising candidate airfoil configurations for VAWTs and to estimate the associated performance gains which could be achieved.

APPROACH

Candidate airfoil shapes were identified from sectional airfoil data, experimental data on rotating blades, and computer analysis or virtual aerodynamics. Airfoil force coefficients were established and the performance estimates were determined for a VAWT(two-bladed rotor configuration)for each airfoil section.

OUTPUT

Performance estimates have been completed and are presented in a final report. The report estimates a C_p increase may be possible with the choice of a $NACA63_2$-015 airfoil in place of NACA 0015.

- SERI/TR-11045-1, June 1982

3.4 Innovative Concepts

Project Title

Mass Flow Augmentation Through Rotors

Management P. Finnegan, (R&TD) (216) 433-4000	**CONTRACT NO.** In-house
Contractor NASA	***Period of Performance*** 1982 to 1985
	FY 81 Funding -0- FY 82 Funding $30,000
Principal Investigator J.M. Savino (216) 433-4000	**CUMULATIVE FUNDING** $30,000
WORK LOCATION Sandusky, Ohio	**CONTRACTING OFFICE** NASA-Lewis Research Center, Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

Rotor tip vanes, an innovative concept, were investigated at Delft University of Technology, the Netherlands. Wind tunnel and towing tests of small scale rotor/tip vane models conducted in the United States showed improvements in rotor energy capture but only for a narrow range of tip speed to wind speed ratios. The Dutch, on the other hand, claim good performance over wind ranges. Tip vanes augment the mass air flow through the circular area swept by the rotor, thereby increasing performance.

OBJECTIVE

The objective of this research is to develop a data base, that currently does not exist, on the performance of a full scale rotor, with tip vanes, over a wide range of rotor speeds and wind velocities.

APPROACH

Existing and future European research reports on rotor tip vanes will be reviewed. Rotor tip vane concepts will be analyzed for application and potential experimental tests on the MOD-0 wind turbine. If research findings warrant full scale tests, they may be accomplished using sub-scale models. Experiments will be conducted to evaluate the performance of a rotor with tip vanes.

OUTPUT

Progress on this task will be periodically reported in weekly and monthly management reports. If full scale MOD-0 tests are conducted, a report will be published at the end of the 4Q FY 1985 on the results of this experimental research. The report will describe the design and fabrication of each blade tip vane configuration, special experimental equipment, experimental procedures, and the processed experimental data will be presented.

3.4 Innovative Concepts

Project Title

THE STRUMMING WINDMILL WIND ENERGY INNOVATIVE SYSTEM ASSESSMENT

Management SERI (303) 231-1379 Richard L.Mitchell	**CONTRACT NO.** XE-0-9173-1
Contractor Payne, Inc. 1933 Lincoln Dr. Annapolis, MD 21401	***Period of Performance*** September 1980 - September 1981
	FY 81 Funding FY82 Funding Carry over FY1980 funding
Principal Investigator Peter R. Payne (301) 268-6150	**CUMULATIVE FUNDING** $40,818
WORK LOCATION Annapolis, MD	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The pitching and rolling of elongated bodies in a stream flow is a common occurance. This phenomenon has the potential for providing the means for the extraction of energy from the wind. Wires, airfoils, and various shapes in the form of long cables, may extract a portion of the energy in the wind and transfer it to linear generators.

OBJECTIVE

The objective of this project is to provide a critical assessment of the technical characteristics and performance of the Strumming Windmill.

APPROACH

The effort will establish aerodynamic and mechanical performance equations and establish the system performance potential. A configurational design will be established along with the establishment of size limitation in the construction of large scale systems.

OUTPUT

The subcontractor will provide a final report containing the analyses and conclusions of the study.

3.4 Innovative Concepts

Project Title

Technical Feasibility of Stand-Alone SWECS

Management Martin J.Deutsch (SERI) (303)231-7085	**CONTRACT NO.** EG-77-C-01-4042
Contractor Solar Energy Research Institute 1617 Cole Blvd. Golden, Co 80401 (303) 231-7085	***Period of Performance*** October 1, 1981 to September 30, 1982
	FY 81 Funding -0- FY82 Funding $85,000
Principal Investigator Martin J.Deutsch (303)231-7085	**CUMULATIVE FUNDING** $85,000
WORK LOCATION Golden, Colorado	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The need to collect appropriate data and evaluate the technical feasibility of stand-alone wind turbine designs for the WECS industry and DOE prompted this investigation.

OBJECTIVE

Evaluate the technical feasibility of advanced stand-alone SWECS design and compare to utility inter-connected systems; investigate the sensitivity to key technical and physical parameters.

APPROACH

Synthesize information on wind turbine designs and performance; wind regime data; battery storage; and energy demand profiles. Evaluate specific designs with SERI computerized WECS performance model. Investigate the sensitivity to demand profiles; wind resource levels and variability; machine design improvements; wind resource/ demand coincidence; and energy utilization.

OUTPUT

Report on the technical feasibility of several stand-alone SWECS designs. Approximate date for SERI draft report is March 1983.

3.4 Innovative Concepts

Project Title

Energy from Humid Air

Management SERI Richard L. Mitchell (303) 231-1379	**CONTRACT NO.** DE-AC01-79ET-23052
Contractor South Dakota School of Mines and Technology Rapid City, South Dakota 57701	***Period of Performance*** February 1979 to March 1980
	FY 81 Funding FY 82 Funding Carry over FY 1979 Funding
Principal Investigator Thomas K. Oliver (605) 394-2454	**CUMULATIVE FUNDING** $168,522
WORK LOCATION Rapid City, South Dakota	**CONTRACTING OFFICE** DOE.Wind Systems Branch

PROJECT SUMMARY

BACKGROUND

A vast amount of energy is contained in the latent heat from vaporization of the water vapor in humid air. Humid air at specific locations could possibly have the potential to provide useful energy.

OBJECTIVE

The objective of this project is to find a technically efficient way of converting the latent heat energy in humid air into mechanical work. This would then be used to drive an electrical generator or alternator. The objective includes the investigation and assessment of the expansion-compression technique.

APPROACH

Studies have been conducted by computer modeling. For humid air, which is made up of dry air plus water vapor, the dry air component is treated as an ideal gas. Properties of the water vapor component have been taken from a computer subroutine for the international steam tables. The expansion-compression technique has been modeled and extensive parametric studies conducted to determine the optimum size system.

OUTPUT

A one-machine mechanization of an expansion-compression cycle making use of vortex flow was assessed to determine whether it has technical potential as a wind energy system for the extraction of the latent heat of condensation from humid air. Results of the research efforts have been presented in a final report.

3.4 Innovative Concepts

Project Title

TETHERED WIND ENERGY SYSTEM ASSESSMENT

Management SERI (303) 231-1379 Richard L. Mitchell	**CONTRACT NO.** XE-0-9172-2
Contractor Tetra-Tech Inc. 630 N. Rosemead Blvd. Pasadena, CA 91107	***Period of Performance*** September 1980 - September 1981
	FY 81 Funding FY82 Funding Carry over FY1980 funding
Principal Investigator Okitsugu Furuya (213) 449-6400	**CUMULATIVE FUNDING** $35,974
WORK LOCATION Pasadena, CA	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The increased energy density in the wind at higher altitudes offers a potential for increased technical performance for wind turbines which are tethered at higher altitudes (including the possibility of the jet stream). This assessment is directed toward the determination of the technical potential of several of the possible configurations for this concept. It is felt that some of these concepts will show a significant technical advantage over others.

OBJECTIVE

The objective of this project is to provide a critical assessment of several different types of concepts for Tethered Wind Energy Conversion Systems.

APPROACH

The study is to address the conceptual designs, aerodynamic characteristics, and power generation and transmission. The study will include the lifting components and generating platform, the power generation componenets, the tethering cables and power transmission cables, and the anchoring components.

OUTPUT

The subcontractor will provide a final report containing a detailed assessment of several tethered WECS concepts and provide a discussion concerning their technical potential.

SERI/TP-09172-2, August 1981

3.4 Innovative Concepts

Project Title

Electrofluid Dynamic (EFD) Wind Driven Generator Program

Management SERI Richard L. Mitchell (303) 231-1379	**CONTRACT NO.** XE-1-1291-1
Contractor University of Dayton Research Institute 30 College Park Avenue Dayton, Ohio 45469	***Period of Performance*** April 1979 - October 1982
	FY 81 Funding Carry over 1979 Funding FY 82 Funding $51,000
Principal Investigator John E. Minardi (513) 229-3845	**CUMULATIVE FUNDING** $315,818
WORK LOCATION Dayton, Ohio	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Research conducted by the U.S. Air Force in the early 1970s demonstrated the Electrofluid Dynamic (EFD) generator concept and provided the scaling laws. Research at the University of Dayton provided EFD wind generator theory and experimentally confirmed the basic principle of EFD power generation.

OBJECTIVE

The primary objectives of this effort are: 1) to provide a sufficient density of charged water droplets of low mobility so that EFD generator geometries can be experimentally evaluated; 2) to provide a system with satisfactory levels and density of charged water droplets of low mobility; and 3) establish a conceptual design for a full-scale generator and evaluate its potential.

APPROACH

Charged droplet production methods and performances of generator designs were investigated in wind tunnel tests. Theoretical investigations of EFD theory were extended and compared with wind tunnel data. A conceptual design was established and analysis of this system is to be carried out.

OUTPUT

Output current and voltage were measured and compared with theoretical predictions to establish research progress and direction of new efforts to lead to the development of practical EFD wind generators. Data and analyses of the test results have been presented in a final report. A description of the conceptual design and the results of the analysis of that design are to be presented in a final report.

3.4 Innovative Concepts

Project Title

Flight Testing of the Tethered Gyromill

Management	**CONTRACT NO.**
Richard L. Mitchell (SERI) (303)231-1379	P.O. (E-1-1306)
Contractor	***Period of Performance***
University of Sydney Dept. of Mechanical Engineering Sydney, NSW 2006 AUSTRALIA	October 1, 1980 to December 31, 1982
	FY 81 Funding FY82 Funding
	$10,000 -0-
Principal Investigator	**CUMULATIVE FUNDING**
B.W. Roberts (Sydney) 692-1122	$10,000
WORK LOCATION	**CONTRACTING OFFICE**
Sydney, Australia	Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The increase in average wind power density which is available at increased altitude represents a significant potential for tethered WECS. DOE-funded studies by Aerospace Systems Inc. and Tetratech Inc. have established the lifting rotor concepts as having a high potential among these systems. Research at the University of Sydney has been underway in this field for several years.

OBJECTIVE

The objective of this project is to flight test a lifting rotor tethered WECS model and establish its stability and performance characteristics.

APPROACH

After the completion of model construction and initial stability testing the tethered gyromill is to undergo hovering tests and finally high altitude (200') power generation testing to establish its performance and stability.

OUTPUT

The results of the stability and power generation flight tests as well as the performance analysis of the tethered gyromill are to be presented in a final report.

3.4 Innovative Concepts

Project Title

Building Heating with a Wind-Driven Induction Generator/Heat Pump

Management USDA-ARS R. N. Clark (806) 378-5721	**CONTRACT NO.** DE-AI01-76ET20319
Contractor USDA-ARS	***Period of Performance*** 3 years
	FY 81 Funding $ 100,000 — FY 82 Funding $ 115,000
Principal Investigator Leo Soderholm (515) 294-5723	**CUMULATIVE FUNDING** $215,000
WORK LOCATION Ames, IA	**CONTRACTING OFFICE** USDA-ARS, Conservation and Production Research Laboratory, Bushland, TX

PROJECT SUMMARY

BACKGROUND As nonrenewable energy sources continue to increase in price or are in short supply, electrical power will likely assume an even larger proportion of the heating load and there will be substantial increases in peak loads on rural electrical distribution systems. An induction generator/heat pump system interfaced to utility power for supplying the backup energy requirements for building heating can both save nonrenewable energy sources and contribute to load factor improvement of the electrical distribution system.

OBJECTIVE To evaluate equipment and techniques for heating rural structures using an induction generator/heat pump approach to conserve nonrenewable energy resources and, through utility interfacing, determine approaches for helping rural power suppliers serve projected increases in electrical power use for structure heating.

APPROACH An induction generator/heat pump heating system will be installed at Bloomfield, Iowa using the latest available and appropriate SWEC's to replace the existing Gruman Windstream 25. This unit is now an obsolete model using a self-excited alternator that is not interfaced to utility power. Design and operating parameters for the wind system will be determined for heating farm buildings as well as metering methods and power transfer with the utility.

OUTPUT

1. Report of performance of a wind-driven induction generator/heat pump
2. Publication of design criteria and design procedures for a wind-driven induction generator/heat pump building heating system
3. Report of research

3.4 Innovative Concepts

Project Title

INNOVATIVE WIND TURBINE

Management SERI Richard L. Mitchell (303) 231-1379	**CONTRACT NO.** XH-0-9260-1
Contractor West Virginia University Morgantown, WV 26506	***Period of Performance*** March 1980 - February 1982
	FY 81 Funding FY82 Funding Carry over FY1980 funding
Principal Investigator Richard E. Walters (304) 293-4111	**CUMULATIVE FUNDING** $463,523
WORK LOCATION Morgantown, WV	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Advanced wind turbine designs are being investigated as possible alternatives to conventional wind turbines. For vertical axis machines, high lift - low drag airfoils are being considered to improve machine performance. One such airfoil is the circulation-controlled airfoil. Previous work on this airfoil at West Virginia University resulted in the development of a successful STOL aircraft which utilizes a circulation-controlled flap design.

OBJECTIVE

The objective of this project is to investigate the technical potential of using circulation-controlled blades on a straight bladed, vertical axis wind turbine. This includes turbine configuration, structural, and aerodynamic analyses, as well as a system component study.

APPROACH

Both theoretical and experimental methods were used to study the performance. The major efforts were to modify the existing vertical axis wind turbine test model to allow the testing of various air supply systems to use in the circulation controlled blowing. Indoor tests are to be performed on the single bladed indoor test apparatus.

OUTPUT

Test data is to be analyzed to determine the preliminary turbine performance with circulation-controlled airfoil sections. Preliminary estimates of the benefits of the circulation-controlled turbine and the air supply system are to be made. Results of this work are to be presented in a final report.

- SERI/TP-09260-1

4.1 Small Systems Development

Project Title

DOE 100 kW VAWT

Management DOE/ALO G. P. Tennyson -- 505-846-3219	**CONTRACT NO.** DE-AC04-78AL04272 August 25, 1981
Contractor Alcoa Laboratories Alcoa Center, PA 15069	***Period of Performance*** August 1979-January 1982
	FY 81 Funding $700,000 — FY82 Funding $51,000
Principal Investigator M. H. Williams	**CUMULATIVE FUNDING** THROUGH FY82 $2,038,000
WORK LOCATION Various Locations	**CONTRACTING OFFICE** DOE/ALO

PROJECT SUMMARY

BACKGROUND - SNL, a DOE R&D facility, directs the program to establish the technical and economic feasibility of the Darrieus VAWTs. The program consists of technology development and systems development. The R&D is in areas of structural dynamics, aerodynamics, low-cost design, fabrication techniques, analytical and design tool refinement, and component systems. In FY79, the first direct application of the technology occurred in the Alcoa-designed and produced DOE 100 kW Darrieus VAWT. SNL provides technical direction.

OBJECTIVE - In December 1978, a DOE assessment of the Darrieus VAWT design determined that sufficient economic potential existed to warrant full-scale development of a 100 kW machine. A low-cost version of the 17-m research machine is the design goal of the program. The objectives of this project are to stimulate involvement of the fabrication oriented industry in manufacturing first-generation VAWT units and to demonstrate the possibilities of the low-cost design.

APPROACH - DOE contracted with Alcoa for design and manufacture of four turbines. SNL provided the technical direction.

OUTPUT - Reports: (1) Phase I, Design and Fabrication; (2) Phase II, Operating and Maintenance; (3) Installation Manual; (4) Specifications for Installation; (5) Final Technical Report: Design and Fabrication of Low-Cost Darrieus Vertical Axis Wind Turbine System Phase II.

Installation and Operations:

Unit # VAWT	Location/Installation	First Turn
1	DOE/Rocky Flats, CO	August 1980
2	USDA, Bushland, TX	March 1981
3	Tisbury Water Board, Martha's Vineyard, MA	June 1981
4	DOE Storage, USDA, Bushland, TX	

4.1 Small Systems Development

Project Title

15 kW System Development

Management Rockwell International W. S. Bollmeier, II (303) 497-7169	**CONTRACT NO.** Enertech PF-07711-T; UTRC PF-93652-T
Contractor Enertech Corporation United Technologies Research Ctr.	***Period of Performance*** October 1, 1980 - September 30, 1982
	FY 81 Funding $1,150,000 ***FY 82 Funding*** -0-
Principal Investigator Enertech-Robert Zickefoose (802) 649-1145 UTRC-Jeff Carstens (203) 727-7238	**CUMULATIVE FUNDING** $3,232,000
WORK LOCATION Contractors' Facilities	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Potential benefits were identified for farm and rural single-phase power applications in the 15 kW size and development contracts were awarded to Enertech and UTRC in FY 1979. Design phases were completed during FY 1980.

OBJECTIVE

- To design and develop a complete 15 kW (nominal) SWECS that are capable of generating electrical energy at a cost competitive with alternate energy sources.

APPROACH

Prototype units were fabricated and tested at the contractor facilities during the winter and spring of 1981. The prototypes were delivered to RF during FY 1982 for subsystem tests, installation, and checkout.

OUTPUT

Contractor Phase I design and analysis reports were completed and published in FY 1982. Phase II fabrication and testing reports were prepared and will be published in FY 1983.

4.1 Small Systems Development

Project Title

8 kW System Development

Management Rockwell International W. S. Bollmeier, II (303) 497-7169	**CONTRACT NO.** Grumman PF-71787-F; UTRC PF-68186-F
Contractor Grumman Energy Systems, Inc. United Technologies Research Ctr. 445 Broad Hollow Road Melville, NY 11747	***Period of Performance*** October 1, 1980 - September 30, 1982
	FY 81 Funding $-0- ***FY 82 Funding*** -0-
Principal Investigator GESI - Frank Adler (516) 567-8065 UTRC - Jeff Carstens (203) 727-7238	**CUMULATIVE FUNDING** $2,259,200
WORK LOCATION Contractors' Facilities	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Since commercially available SWECS in the 8 kW range were judged expensive and unreliable, development contracts were issued in FY 1978. Through FY 1980 three prototype units had been delivered and all underwent test evaluation at RF. One contract (Windworks) was cancelled for Rockwell convenience effective September 30, 1980.

OBJECTIVE

To design, fabricate, and test prototype 8 kW (nominal) SWECS that will satisfy the need of various residential or small farm applications in a cost-effective manner.

APPROACH

During FY 1981, primary activities were concentrated on closing out the development contracts and completing the Phase I and II design reports. Phase II atmospheric testing of the prototypes was completed.

OUTPUT

Contractor Phase I and II reports were published and disseminated in FY 1980. The final RF data will be published in FY 1983.

4.1 Small Systems Development

Project Title

40 kW System Development

Management Rockwell International W. S. Bollmeier, II (303) 497-7169	**CONTRACT NO.** Kaman PF-69895; McDonnell PF-64100
Contractor Kaman Aerospace Corporation McDonnell Aircraft Company	***Period of Performance*** October 1, 1980 - September 30, 1982
	FY 81 Funding $199,000 ***FY 82 Funding*** -0-
Principal Investigator Kaman - Bruce Goodale (203) 242-4461 McAIR - Robert Brulle (314) 233-2215	**CUMULATIVE FUNDING** $4,455,000
WORK LOCATION Contractors' Facility	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Preliminary assessment of markets and applications in FY 1977 led to the specification for a 40 kW SWECS and award of two development contracts in FY 1978. Through FY 1980 the two designs were finalized and prototypes delivered.

OBJECTIVE

- To design, fabricate, and test prototype 40 (nominal) kW SWECS that will satisfy the needs of various farm and other rural applications in a cost effective manner.

APPROACH

The prototype units underwent atmospheric, vibration, and dynamometer testing at RF and contractor Phase II reports were written.

OUTPUT

Phase I design and analysis reports were completed and published in FY 1981. Phase II fabrication and test reports were published in FY 1982. Rocky Flats test experience will be documented in a summary report to be published in 1983.

4.1 Small Systems Development

Project Title

4 kW System Development

Management Rockwell International W.S. Bollmeier, II (303) 497-7169	**CONTRACT NO.** SCI PF-07420-C; Tumac PF-08194-N; North Wind PF-08501-C
Contractor North Wind Power Company Structural Composites Industries (SCI) Tumac Industries	***Period of Performance*** October 1, 1980 to September 30, 1982[1]
	FY 81 Funding FY 82 Funding $1,425,000 -0-
Principal Investigator 1	**CUMULATIVE FUNDING** $3,666,000
WORK LOCATION Contractor's Facilities	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Markets for SWECS in the 4 kW size range have been identified for electrical (non-heating) needs in residential applications. Systems requirements were developed for a COE goal of 6c/kWh (in 10 mph average wind speed). Three contracts were awarded in FY 1980.

OBJECTIVE

To design, fabricate, and test prototype 4 kW (nominal) SWECS to satisfy the energy requirements for isolated, small residential applications in conjunction with an auxiliary generator or intertied with a utility.

APPROACH

The three contracts continued through the design phase in early FY 1981. Prototype units were fabricated and tested at the contractor facilities during the winter/spring of FY 1981. The SCI contract was terminated at Phase I due to cost overruns and probable failure of the machine to approach COE goals. The remaining two contractors delivered their units to Rocky Flats in FY 1982.

OUTPUT

The SCI Phase I report was published in FY 1982. Contractor Phase I reports for other prototypes were written and will be published in FY 1982. This project will be completed during FY 1982. The Rocky Flats final data reports and contractor Phase II reports will be completed in FY 1983.

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[1] NWPCo - Don Mayer (802) 496-2955
SCI - Robert L. Gordon (714) 594-7777
Tumac - Jim McConnell (303) 596-4400

4.1 Small Systems Development

Project Title

Cooperative and Industry-Funded Tests

Management Rockwell International A. R. Trenka (303) 497-7127	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1981 - September 30, 1982
	FY 81 Funding -0- ***FY 82 Funding*** $10,000
Principal Investigator L. M. Steward (303) 497-7181	**CUMULATIVE FUNDING** $10,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

Most businesses comprising the small wind systems industry do not have the facilities or the test experience required for the exhaustive testing necessary to put a safe, reliable product on the market. The Rocky Flats test site is an established, fully instrumented facility which could be used by private companies to reduce the use of inefficient trial-and-error design.

OBJECTIVE

- Use government facilities to support research laboratories, utilities, universities, government agencies, and the wind system industry in the design and production of safer, more efficient, more reliable wind systems.

APPROACH

Following DOE approval of the concept and the establishment of contract agreement procedures, tests and analyses were conducted as requested by private companies. Activities ranged from the generation of power curves to highly detailed component tests and performance optimization analyses. Data from these tests may be utilized in Rocky Flats model development, analyses, and R&D without violation of proprietary information.

OUTPUT

Information obtained by manufacturers will result in an overall improvement of the technology. "Generic" data obtained by Rocky Flats will also be valuable in providing input to the entire range of DOE-funded small wind systems research efforts.

4.2 Intermediate Systems Development

Project Title

Field Test and Evaluation of Intermediate and Large Wind Turbines

Management James Couch (216) 433-4000	**CONTRACT NO.** DEN3-141, DEN3-265, DEN3-315, DEN3-233
Contractor Mod-0A: Clayton, NM; Block Island Power Co.; Hawaiian Electric Co; Culebra Mod-1: Blue Ridge Elec. Membership Corp Mod-2: Bonneville Power Association	***Period of Performance*** 1977 to 1982 ***FY 81 Funding*** $100,000 FY 82 Funding $70,000
Principal Investigator Eli Garcia (Clayton); Franklin Renz (BIPCO); Thomas Jezierny (HECO); Grant Ayers (BREMCO); Gary Stemler (BPA); & Orlando Anglero (Culebra)	**CUMULATIVE FUNDING** $370,000*
WORK LOCATION Clayton, NM; Block Island, RI; Oahu, HI; Boone, NC	**CONTRACTING OFFICE** NASA Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

The large wind turbine field test and evaluation program consists of four Mod-0A's, one Mod-1, and three Mod-2's. The Mod-2's are installed in a three-machine cluster; the others are installed at individual sites. There is a need to obtain operation and performance data while gaining experience in the operation of large wind turbines in typical user environments.

OBJECTIVE

The objective is to determine machine performance, power quality, reliability, and maintenance requirements of wind turbines in operating utility environments.

APPROACH

Field sites proposed by utility organizations were competitively selected for installation of the intermediate and large wind systems. After the experimental test period, a decision is reached as to disposition of the machines including such option as to: (1) conduct additional experimental tests, (2) turn the machine over to the participating utility or other qualified organization, or (3) dismantle and remove the machine. This activity provided special maintenance supplied by the host utility.

OUTPUT

The experimental results are evaluated and presented at various workshops and in technical publications. Most recently, results were presented at Wind Workshop V held in Washington, DC in October 1981. Results are also published through cooperative arrangement with the Electric Power Research Institute. Tests of the Mod-0A's and the Mod-1 have been completed. Final reports on the Mod-0A and Mod-1 Projects will be published in FY 83.

*Does not include cooperative funding by utilities.

4.3 Large Systems Development

Project Title Field Tests of Experimental 2 MW Wind Turbine Design (Mod-1)

Management James Couch (216) 433-4000	**CONTRACT NO.** NAS3-20058
Contractor General Electric Company P. O. Box 8661 Philadelphia, PA 19101	***Period of Performance*** November 1974 - September 1982 ***FY 81 Funding*** $0 FY 82 Funding $0
Principal Investigator Richard H. Poor, 215-962-2352	**CUMULATIVE FUNDING** $26,000,000
WORK LOCATION Valley Forge, PA and Boone, NC	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

An objective of the Federal Wind Energy Program is to develop the technology for practical wind turbines that supply significant amounts of cost-competitive electrical energy. Wind turbine loads and system response were not well known during the period that the Mod-1 was designed. When the installation of the 2 MW Mod-1 was completed, it was the world's largest wind turbine. The Mod-1 was shut down in January 1981 following a failure in its drive train. It is now being disassembled and removed.

OBJECTIVE

The overall objective of the 2 MW Mod-1 Wind Turbine Project was to obtain early engineering, operational and performance data. In addition, an evaluation of data was conducted and used to assist in the design of more advanced wind turbines.

APPROACH

Engineering data was taken during machine operation to assess energy conversion and performance, and to evaluate loads and dynamic responses. In other planned tests, data was taken to assess the environmental influence of the machine on humans and their life style in the community around the machine. Sound, as emitted by the machine, was investigated as well as its propagation in the community. Static and dynamic testing was done at various locations to assess the interference to television reception caused by the machine.

OUTPUT

Verification of analytical computer codes used to predict wind turbine dynamic response and loads analysis was a significant contribution to the data bank of wind turbine technology. Evaluating the environmental effects of sound and television interference will be of assistance for future wind turbine siting considerations. A new computer code was developed to predict sound levels generated by wind turbines which has been of value in designing advanced wind turbines. The 2 MW Mod-1 Wind Turbine Project has been completed. Twelve formal reports were published as a result of this project. A final report on the Project will be published in FY 83.

4.3 Large Systems Development

Project Title

Design, Fabricate, and Test Three Experimental 300-Foot Diameter Wind Turbines (Mod-2)

Management Larry H. Gordon (216) 433-4000	**CONTRACT NO.** DEN3-2
Contractor Boeing Engineering & Construction Company 625 Andover Park West Tukwila, Washington 98188	***Period of Performance*** August 1977 to December 1984
	FY 81 Funding FY 82 Funding $3,900,000 $1,900,000
Principal Investigator M.L. Bovarnick (206) 575-5959	**CUMULATIVE FUNDING** $39,000,000
WORK LOCATION Seattle, Washington and Goldendale, Washington	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

On the basis of first generation technology, the second generation Mod-2 concentrated on the technology necessary for 300 ft. diameter rotors and 30 year service life for large multi-megawatt turbines. Innovations were developed pertaining to teetered rotors, partial span pitch control, soft shell towers, epicyclic gearbox, and the use of a quill shaft in the low speed drivetrain. In addition, the feasibility of such wind turbines operating in a cluster in a network needed to be demonstrated.

OBJECTIVE

The objective of this project is to establish the design and to determine the performance, present, cost, operation and maintenance cost, and practicality of manufacturing a large multi-megawatt wind turbine.

APPROACH

NASA is managing this project which established a baseline design for the Mod-2, the cost sensitivity of the design to various configuration alternatives, updated cost estimates at several NASA/DOE design review stages, built and began installation of three experimental wind turbines on a single user site at Goodnoe Hills near Goldendale, Washington. The participating utility is the Bonneville Power Administration. Cluster research testing is being conducted in the areas of aerodynamic research, structural dynamic and aeroelasticity, and multiple systems interactions.

OUTPUT

The three Mod-2 wind turbines were dedicated in May 1981. The machines were shut down for several months in 1981 while problems caused by an overspeed incident were identified and corrected. Aerodynamic, structural dynamic, acoustic, television interference, and machine wake flow interaction tests were run during FY 82.

4.3 Large Systems Development

Project Title Design, Fabricate and Install Advanced, Multi-Megawatt Wind Turbine (Mod-5)	
Management Thomas Cahill, 216-433-4000	**CONTRACT NO.** DEN3-153, DEN3-200
Contractor General Electric Company The Boeing Engineering and Construction Company	***Period of Performance*** 1980 - 1985
	FY 81 Funding $11,800,000 FY 82 Funding $15,399,000
Principal Investigator R. Douglas, 206-575,5931 (BEC) L. Terrey, 215-962-1229 (GE)	**CUMULATIVE FUNDING** $32,299,000
WORK LOCATION Seattle, WA (BEC) Philadelphia, PA (GE)	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

The Mod-5 wind turbine is the third in a succession of progressively larger horizontal axis wind turbine projects. Two contractors were selected by competitive procurement to pursue parallel programs. Both contractors began work in September 1980.

OBJECTIVE

Perform and design development, fabricate, install and validate the safe and reliable performance of two independent prototype wind turbines to deliver energy compatible with existing utility networks, at or below, an estimated cost of 3.75¢ (1980 dollars) when produced in quantity and installed at a site having a mean annual wind speed of at least

APPROACH

6.3 m/s (14 mph).

NASA Lewis Research Center will manage the design, developmental and test effort of the two contractors who were selected by a competitive procurement to perform the work in parallel. Tooling, fabrication, and erection of the wind turbines will be funded and managed by the contractors and/or a utility customer. After check-out and acceptance of each wind turbine, the contractors will collect data and provide performance and systems operation data to NASA for a period of three years.

OUTPUT

The output of this project will be design, analysis and test information, including a final report published in FY 1985. The report will document all of the design and developmental work done by each contractor to arrive at the final design. Drawings and specifications will be produced which completely define each machine and associated tooling and equipment in the as built configuration. Performance and system operation data and analysis for a three year operation period will be provided by each contractor in the form of semi-annual reports.

4.3 Large Systems Development

Project Title Maintenance Support for Intermediate and Large Wind Turbine Field Tests

Management James Couch (Mod-0A & 1) Larry H. Gordon (Mod-2)	**CONTRACT NO.** DEN3-275, DEN3-199, DEN3-216
Contractor Westinghouse Electric Co. (Mod-0A) General Electric Co. (Mod-1) Boeing Engineering & Construction Co. (Mod-2)	**Period of Performance** 1977 - 1983 **FY 81 Funding** $1,900,000 FY 82 Funding $1,500,000
Principal Investigator Thomas Crouse (Mod-0A), 412-928-4731; Richard H. Poor (Mod-1), 215-962-2352; M. L. Bovarnick (Mod-2), 206-575-5959	**CUMULATIVE FUNDING** $8,500,000
WORK LOCATION Clayton, NM; Culebra, PR; Block Island, RI; Oahu, HI; Boone, NC; Goldendale, WA	**CONTRACTING OFFICE** NASA-Lewis Research Center Cleveland, Ohio

PROJECT SUMMARY

BACKGROUND

The large wind turbine field test program consists of four Mod-0A's, one Mod-1 and three Mod-2's. The Mod-2's are installed in a three-machine cluster; the others are installed at individual sites. There is a need to monitor performance and perform non-routine maintenance and repairs on these machines.

OBJECTIVE

The objective is to obtain long term operational field experience on large wind turbines installed in real utility environments.

APPROACH

Performance of each Mod-0A, the Mod-1, and each Mod-2 machine is assessed by NASA. As a result, machine improvements have been incorporated. These improvements are intended to: (1) increase the energy production, (2) reduce major non-routine maintenance, and (3) improve overall reliability.

OUTPUT

These experiences are summarized and presented at various workshops and in technical publications. Most recently, results were presented at Wind Workshop V held in Washington, DC in October 1981. Results are also published through cooperative arrangement with the Electric Power Research Institute. Tests of the Mod-0A's and the Mod-1 have been completed. Final reports on the Mod-0A and the Mod-1 Projects will be published in FY 84.

Project Title

Energy from the Wind - Annotated Bibliography

Management H.Sklar (SERI) (303)231-1939 FTS: 327-1939	**CONTRACT NO.** XE-0-9261-1
Contractor Colorado State University Fort Collins, Colorado	***Period of Performance*** July 1980 to April 1982
	FY 81 Funding $2,032 FY82 Funding $990
Principal Investigator B.Burke (303)491-8694	**CUMULATIVE FUNDING** $19,858
WORK LOCATION Fort Collins, Colorado	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

CSU had produced a basic bibliography in 1975 and supplements, in 1977 and 1979.

OBJECTIVE

Revise and update bibliography.

APPROACH

Revise basic bibliography and first supplement into a computer-compatible format. Produce a third supplement containing entries collected after 1979. Produce cumulative author, subject, report number and conference proceeding indexes.

OUTPUT

Energy from the Wind, Third Supplement, April 1982
Energy from the Wind, Cumulative Indexes to Basic Volume and First-Third Supplements, April 1982.

Project Title

Foreign Applications and Export Potential for Wind Energy Systems

Management H.Sklar (SERI) (303)231-1939	**CONTRACT NO.** XE-1-1093-1
Contractor PRC Systems Services Co. 7600 Old Springhouse Road McLean, Virginia 22102	***Period of Performance*** February 1981 to February 1982
	FY 81 Funding $161,306 — FY82 Funding -0-
Principal Investigator S.Griffith (703)556-1500	**CUMULATIVE FUNDING** $161,306
WORK LOCATION McLean, Virginia	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

The Wind Energy Systems Act of 1980 requires a DOE study and reports on foreign applications and export potential for wind energy systems.

OBJECTIVE

Evaluate foreign applications and export potential for wind energy systems.

APPROACH

Data on wind resources, imports, import restrictions, licensing requirements, exchange controls, dependence on energy imports and balance-of-payments were collected for 184 countries and territories. Data on 27 wind applications were also collected, a catalogue of wind machines suitable for export was developed and each application was evaluated as a function of wind speed, projected wind machine cost and appropriate discount rate.

OUTPUT

DOE Report to Congress: Prospects for Foreign Applications of Wind Energy Systems, Preliminary report, December 1981.

Project Title

Information Dissemination Packet for Extension Agents

Management USDA-ARS R.N. Clark (806) 378-5721	**CONTRACT NO.** DE-AI01-76ET20319
Contractor Southern Agricultural Energy Center	***Period of Performance*** 1 year
	FY 81 Funding $29,000 FY 82 Funding -0-
Principal Investigator Marvin Hall (912) 386-3585	**CUMULATIVE FUNDING** $29,000
WORK LOCATION Tifton, Gerogia	**CONTRACTING OFFICE** USDA-ARS, Conservation and Production Research Laboratory, Bushland, Texas

PROJECT SUMMARY

BACKGROUND

Technical assistance was provided to Agricultural extension agents and the general public to help them become more knowledgeable about current wind energy research and development.

OBJECTIVE

To prepare an informational packet containing slides, tapes, instructional and reference materials for agricultural extension agents and the general public.

APPROACH

The USDA Information Division would develop a general slide-tape presentation using current research results showing the advantages and application of wind energy systems. Written materials would be supplied in the form of a teacher guide for conducting one to two hour short courses on wind energy systems. Final reference information for more detailed studies would be included.

OUTPUT

Slides, tapes, and instructional material.

Project Title
Technical Information Dissemination

Management Rockwell International Terry J. Healy (303) 497-7111	**CONTRACT NO.** DE-AC04-76DP03533
Contractor Rockwell International	***Period of Performance*** October 1, 1980 - September 30, 1981
	FY 81 Funding $200,000 ***FY 82 Funding*** -0-
Principal Investigator D. M. Dodge (303) 497-7174	**CUMULATIVE FUNDING** $600,000
WORK LOCATION DOE Rocky Flats Plant, Golden, Colorado	**CONTRACTING OFFICE** Rocky Flats Area Office

PROJECT SUMMARY

BACKGROUND

For several years, RF undertook information outreach activities as a regular part of its program. Together with continued liaison with state and other agencies required by the Field Evaluation Program and direct communication with the Regional Solar Energy Centers (RSEC's) and the public, RF developed a unique understanding of target audience needs.

OBJECTIVE

To resolve SWECS legal, institutional, and environmental issues.

APPROACH

This project involved preparation of special publications, such as information packages, equipment checklists, SWECS performance summary sheets; distribution of special publications to compiled mailing lists; the exhibition of displays at energy tours and exhibitions; and coordination of a SWECS industry workshop in the Rocky Flats area in support of the Fifth Biennial Workshop on WECS. The project was terminated at the end of FY 1981.

OUTPUT

In general terms, the output of this task increased public awareness of SWECS benefits in support of program goals. Tangible products include brochures, SWECS promotion materials, data sheets, special guides designed for use by the public, government agencies and other groups crucial to the commercialization process; and prompt distribution of information materials to requestors. Small Wind Turbine Systems Workshop was held in May 1981 in support of the Fifth Biennial Workshop.

Project Title

Wind Workshops and Information Development

Management Robert Noun (SERI) (303)231-1263	**CONTRACT NO.** EG-77-C-01-4042
Contractor Solar Energy Research Institute 1617 Cole Blvd. Golden, Colorado 80401	***Period of Performance*** October 1, 1980 to September 30, 1982 ***FY 81 Funding*** FY82 Funding $140,000 $70,000
Principal Investigator Kate Blattenbauer (303)231-7375	**CUMULATIVE FUNDING** $210,000
WORK LOCATION Golden, Colorado	**CONTRACTING OFFICE** Solar Energy Research Institute

PROJECT SUMMARY

BACKGROUND

Accurate and timely technical information on federal government-sponsored wind energy research is crucial to the wind energy industry. SERI's wind energy information and workshops project is intended to communicate the results of research to the wind energy community.

OBJECTIVE

Advance the scientific understanding of wind energy technology by reporting on the technical results of federal wind energy research.

APPROACH

Plan, coordinate and conduct technical workshops on wind energy as required by DOE and develop technical information products on wind system research.

OUTPUT

- Proceedings of the 1981 Rocky Flats Small Wind Turbine Systems Workshop.
- Windpower MOD-2 pamphlet.
- Proceedings of the Fifth Biennial Wind Energy Workshop and Conference
- Proceedings of the NASA Large Horizontal Axis Wind Turbines Workshop