ANNUAL REPORT OF THE CENTER FOR ENERGY AND COMBUSTION RESEARCH

University of California, San Diego

July 1, 1993 – June 30, 1994

1. Summary and Plans for the Coming Year

This center, previously known as the UCSD Energy Center, was given its new name in 1986 to underscore the close link on campus between energy and combustion research. Approximately twenty faculty and professional staff members are affiliated informally with CECR.

Since its origins, the center has focused on basic problems in finding new sources of energy and the social, environmental, economic, and political consequences of energy consumption, including combustion. Studies range from investigations into the fundamental nature of energy and combustion to practical applications in energy conservation and production, as well as pollution control.

Current research includes fundamental studies in combustion related to rocket propulsion, to power production and soot production by hydrocarbon fuels, and to use of solid-propellant fuels and sprays in combustion chambers. Three specific new grants are for "Prediction of NO_x Emissions from Large Diesels," from the Office of Naval Research, for "Fundamental Studies of Spray Combustion" from the Department of Energy, and for "High-Pressure Combustion of Binary Fuel Sprays" from NASA.

The Center for Energy and Combustion Research has brought together researchers from Brasil, Germany, France, Spain, Japan, China and Canada for brief periods of study and of exchange of ideas during this period.

Plans for the 1994-95 academic year include further emphasis on the fluid dynamics of reacting flows relevant to propulsion and on chemical aspects of propulsion and energy problems. Proposals have been submitted to the Air Force Office of Scientific Research for research on, "Theories of Turbulent Combustion in High Speed Flows", and to NASA on, "Scientific Support for a Proposed Space Shuttle Droplet Burning Experiment", for example. In addition, plans are under way for seeking a large grant for a MURI with the Department of Defense, jointly with researchers in the Department of Chemistry at UCSD.

2. Advisory Committee

The Advisory Committee for this time period is composed of:

Mr. Gary D. Cotton
Senior Vice-President
Engineering and Operations
San Diego Gas & Electric

Dr. Edward A. Frieman
Director
Scripps Institution of Oceanography

Dr. Alan C. Kolb
Chairman and Chief Executive Officer
Maxwell Laboratories, Inc.

These individuals have been serving at the request of the Director of the Center, who consults with them mainly individually. Plans are being formulated to arrange for a more formal manner of appointment to the advisory committee and for a larger representation from within UCSD, especially outside the hard sciences.

3. Faculty and Researchers

Active faculty participants during the period July 1, 1993 - June 30, 1994 included Director Forman A. Williams, Associate Director K. Seshadri, as well as Abraham L. Berlad, Robert J. Cattolica, Alvin S. Gordon, Paul A. Libby, Stanford S. Penner, Sutanu Sarkar and Massoud T. Simnad.

Faculty affiliated with the Center include David Benson, Juan C. Lasheras, David R. Miller, Marc Meyers and Keiko Nomura.

Professional Researchers during the period 1993 - 94 included G. Balakrishnan, Jong Soo Kim, Shui-Chi Li, and Kurt O. Lund.

4. Graduate and Postdoctoral Students

The number of graduate and post-doctoral students directly contributing to the unit who were on the unit's payroll or participated through assistantships, fellowships, or traineeships during this period was 12, and the number who were otherwise involved in the unit's work was 2. The latter group is composed mainly of students who work part time in the combustion laboratory.

5. Instructional Programs

Undergraduate and graduate instruction were offered, as in prior years, on energy- and combustion-related topics within the Department of AMES and the Program on Science, Technology and Public Affairs.

The ORU sponsors a general series of seminars and public lectures in its areas of activities. A listing of these seminars is given in the following table.

	DATE	TOPIC
Pedro García-Ybarra	October 29, 1993	"Experimental Evidence of Self-Excited Relaxation Oscillations Leading to Homoclinic Behavior in Spreading Flames"
Harsha K. Chelliah	November 2, 1993	"Numerical Modeling of Carbon Combustion"
Shui-Chi Li	January 18, 1994	"Experimental Investigation of a Premixed Flame in an Impinging Turbulent Stream"
Kermit Smyth	January 26, 1994	"Laser Imaging of Chemistry, Flow-Field Interactions in Fluctuating Diffusion Flames"
A. K. Oppenheim	January 27, 1994	"Some Reflections upon Turbulent Combustion"
Jong Soo Kim	February 1, 1994	"Response of Strained Diffusion Flames to Periodically Oscillating Pressure and Strain Rate"
Forman A. Williams	February 8, 1994	"NO_x Formation in Diffusion Flames"
Pedro García-Ybarra	February 15, 1994	"Asymptotic Analysis of the Head-on Quenching of a Premixed Flame"
Antonio Sanchez	February 22, 1994	"A Bifurcation Analysis of High-Temperature Ignition of H_2-O_2 Diffusion Flames"
Graham Jones	February 28, 1994	"Status of Magnetic Bearings for Gas Circulators"

SEMINAR SPEAKER	DATE	TOPIC
G. Balakrishnan	March 1, 1994	"Ignition and Extinction Limits in H_2-Air Nonpremixed Systems"
Harold Agnew	March 2, 1994	"Perspectives on Nuclear Energy"
Maria Rightley	March 8, 1994	"Analytic Approximations for Structures of Wet CO Flames with One-Step Reduced Chemistry"
Herbert York	March 9, 1994	"Status of Nuclear Weapons and Nuclear Proliferation"
Vahid Majidi	March 16, 1994	"Chemical Instrumentation for Evaluation of Combustion Byproducts"
Norbert Peters	March 24, 1994	"Partially Premixed Turbulent Diffusion Flames"
John Hewson	April 1, 1994	"CO and NO_x Emission from Laminar Coflow Diffusion Flames"
John Lee	April 8, 1994	"On the Initiation and Stabilization of Detonation Waves"
John Card	April 15, 1994	"Influences of Flame-Vortex Interactions on Formation of NO_x"
Dietmar Trees	April 22, 1994	"Experimental Studies on the Extinction of Counterflow Diffusion Flames"
Bai-Li Zhang	April 29, 1994	"Application of Rate-Ratio Asymptotics to the Prediction of Extinction for Methanol Droplet Combustion"
Carlos Fernandez-Pello	May 6, 1994	"On Ignition and Flame Spread"
David Farley	May 12, 1994	"Electron Impact Ionization Fluorescence of CO2 and N2 for Gas Diagnostics"
K. Seshadri	May 20, 1994	"Chemical Inhibition of Flames"
Mario Molina	May 25, 1994	"Chemistry of Stratospheric Ozone Depletion"

SEMINAR SPEAKER	DATE	TOPIC
Al Gordon	May 27, 1994	"Mechanism of Soot Formation"
Nenad Ilincic	June 3, 1994	"Kinetics of NO_2 Methane Nonpremixed Flame"

6. Participation From Other Organizations

A number of specialists from other organizations working on energy and combustion research have been regular visitors to UCSD and have participated in campus programs through formal lectures and informal discussions. For July 1, 1993 - June 30, 1994, these include:

VISITOR	AFFILIATION
Demetrio Bastos-Netto	Instituto Nacional de Pesquisas Espaciais Cachoeira Paulista, Brasil
John Card	Sandia National Laboratories Livermore, California
Michel Champion	ENSMA Poitiers, France
Harsha K. Chelliah	University of Virginia Charlottesville, Virginia
Paul Clavin	Universite Aix Marseilles Marseilles, France
Fernando Fachini	Instituto Nacional de Pesquisas Espaciais Cachoeira Paulista, Brasil
Carlos Fernandez-Pello	University of California Berkeley, California
Pedro García-Ybarra	Universidad Nacional de Educación a Distancia Madrid, Spain
Adelbert Grudno	RWTH Aachen Aachen, Germany
Mathias Klug	RWTH Aachen Aachen, Germany
John Lee	McGill University Montreal, Canada
Amable Liñán	Ciudad Universitaria Madrid, Spain

VISITOR	AFFILIATION
Vahid Majidi	University of Kentucky Lexington, Kentucky
Mario Molina	Massachusetts Institute of Technology Cambridge, Massachusetts
Takashi Niioka	Institute of Fluid Science, Tohoku University Sendai, Japan
Antoni K. Oppenheim	University of California Berkeley, California
Norbert Peters	RWTH Aachen Aachen, Germany
Jun'ichi Sato	IHI Research Institute Tokyo, Japan
Kermit Smyth	National Institute of Standards and Technology Gaithersburg, Maryland
Dietmar Trees	RWTH Aachen Germany
Thomas Weisweiller	RWTH Aachen Germany
Sun Yi	Energy Conservation Technology Center Harbin, China

7. Public Relations Activities

Faculty and staff members associated with the UCSD Center for Energy and Combustion Research continue to be involved in energy policy and analysis activities and studies at local, state, national and international levels. The editorial offices for Energy, The International Journal (published by Pergamon Press in London, England, since 1975) remain housed at the UCSD Center for Energy and Combustion Research. S. S. Penner is the Chairman of the Panel of Experts for the California Council on Science and Technology advising the Integrated Waste Management Board of the State of California. He also directs a study on Needs in Fundamental Combustion Research to Support Industrial Applications for the Department of Energy. F. A. Williams serves on the Advisory Committee of the University-wide Energy Research Group and advises the California Air Resources Board on combustion-related problems. A. S. Gordon serves on the Research Screening Committee of the California Air Resources Board. At the international level, participants continue to interact abroad on energy and combustion issues. For example, Williams delivered invited presentations at the International Workshop on Chaos and Turbulence in Tsukuba, Japan and at the joint Italian/Spanish meeting of the Combustion Institute in Stresa, Italy. There is continuing joint research with investigators at Cambridge University, England, RWTH Aachen, Germany, Université de Provence, Marseilles, France, University of Madrid, Spain, and elsewhere.

8. Publications

1. Ikeda, H., Libby, P.A., Williams, F.A. and Sato, J., "Catalytic Combustion of Hydrogen-air Mixtures in Stagnation Flows," *Combustion and Flame* Vol. 93 (1993) 138-148.

2. Li, S.C., Libby, P.A. and Williams, F.A., "Spray Structure in Counterflowing Streams with and without a Flame," *Combustion and Flame* Vol. 94 (1993) 161-177.

3. Li, S. C., Libby, P. A. and Williams, F. A., "Oscillations of a Sphere in Counterflowing Streams," Western States Meeting, The Combustion Institute, Salt Lake City, Utah, March 22-23, 1993, 15 pages.

4. Li, S. C., Libby, P. A. and Williams, F. A., "An Experimental and Theoretical Study on Spray Structure in Two-Phase Counterflowing Streams with and without a Flame," 29th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, Paper Number: AIAA 93-1769, Monterey, California, June 28-30, 1993, 17 pages.

5. Li, S. C., Libby, P. A. and Williams, F. A., "Turbulent Sprays in a Stagnation Flow with and without a Flame" 14th International Colloquium on Dynamics of Explosions and Reactive Systems , Paper Number: C8.6.1, University of Coimbra, Coimbra, Portugal, August 1-6, 1993, 18 pages.

6. Li, S. C., Libby, P. A. and Williams, F. A., "Experimental Investigation of Turbulent Flame in a Reactant Stream Impinging on a Wall," Eastern States Meeting, The Combustion Institute, Princeton, NJ, October 25-27, 1993, 19 pages.

7. Li, S. C., Libby, P. A. and Williams, F. A., "A laminar Counterflow in a Narrow Channel," the 46th Meeting of the American Physical Society, Albuquerque, NW, November 21-23, 1993, 15 pages.

8. S. S. Penner, "Combustion Research in Waste Incineration," Festschrift in Honor of A. K. Oppenheim, Springier Verlag (1993).

9. S. S. Penner, "A Low-Cost/No Regrets View of Greenhouse Gas Emissions (GHGE) and Global Warming (GW)," Journal of Clean Technology and Environmental Sciences (1993).

10. G. Erlebacher and S. Sarkar, "Statistical Analysis of the Rate of Strain Tensor in Compressible Homogeneous Turbulence," *Phys. Fluids* A, **5**, 3240-3254 (1993).

11. A.O. Demuren and S. Sarkar, "Perspective: Systematic Study of Reynolds Stress Closure Models in the Computations of Plane Channel Flows," *ASME J. Fluids* Eng., **115**, 5-12 (1993).

12. Seshadri, K. and Williams, F. A., "Reduced Chemical Systems and their Applications in Turbulent Combustion," Turbulent Reacting Flows (Eds. P. A. Libby and F. A. Williams), Chapter 4, Academic Press, New York, 1993.

13. Seshadri, K., Peters, N. and Williams, F. A., Asymptotic Analysis of Stoichiometric and Lean Hydrogen-Air Flames, Combustion and Flame, 1993.

14. A. Liñán and F.A. Williams, "Ignition in an Unsteady Mixing Layer Subject to Strain and Variable Pressure," Combustion and Flame 95, 31-46 (1993).

15. F.A. Williams, "Theory of Steady, One-Dimensional, Laminar Flame Propagation," Chapter 2 of Modern Developments in Energy, Combustion and Spectroscopy in Honor of S.S. Penner, (F.A. Williams, A.K. Oppenheim, D.B. Olfe and M. Lapp, editors), Pergamon Press, New York, 1993, pp. 15-27.

16. S.C. Li, P.A. Libby and F.A. Williams, "Droplet Relative Motion and Spray Structure in Counterflowing Streams," Fluid Mechanics and Heat Transfer in Sprays, (J.W. Hoyt, T.J. O'Hern, C. Presser, A.K. Gupta and R.L. Alpert, editors), American Society of Mechanical Engineers, New York, 1993, pp. 25-34.

17. J.S. Kim and F.A. Williams, "Structure of Flow and Mixture-Fraction Fields for Counterflow Diffusion Flames with Small Stoichiometric Mixture Fractions," SIAM Journal on Applied Mathematics 53, 1551-1566 (1993).

18. S. C. Li, Paul A. Libby and F. A. Williams, "Experimental Investigation of a Premixed Flame in an Impinging Turbulent Stream" CECR Report 93-03.

19. G. Balakrishnan, M. D. Smooke and F. A. Williams, "A Numerical Investigation of Extinction and Ignition Limits in Laminar Nonpremixed Counterflowing Hydrogen-Air Streams for both Elementary and Reduced Chemistry" CECR Report 93-04.

20. A. L. Sánchez, A. Liñán and F. A. Williams, "A Bifurcation Analysis of High-Temperature Ignition of H_2-O_2 Diffusion Flames" CECR Report 93-05.

21. M. Rightley and F. A. Williams, "Analytical Approximations for Structures of Wet CO Flames with One-Step Reduced Chemistry" CECR Report 93-06.

22. B. L. Zhang, J. M. Card and F. A. Williams, "Application of Rate-Ratio Asymptotics to the Prediction of Extinction for Methanol Droplet Combustion" CECR Report 93-07.

23. R. J. Cattolica and T. G. Mataga, "OH Rotational Temperature Measurements in Hypersonic Shock Waves," Rarefied Gas Dynamics, p. 79-89, AIAA Progress Series, Vol. 158, R. A. Seebass, Ed., AIAA, Washington D. C., 1994.

24. A.S. Gordon, S.C. Li, P.A. Libby, and F.A. Williams, "Influence of Initial Velocity Distributions on the Height of Methane-Air Non-Premixed Flames," Combust. Sci. and Technol. 100: (1994), 395-399. From In Preparation. (Changed title from, "Flame Height as a Function of Fuel Velocity Relative to Air Velocity").

25. Li, S. C., Libby, P. A. and Williams, F. A., "Experimental and theoretical studies on Stagnation Turbulent Sprays," 12th U.S. National Congress of Applied Mechanics for presentation and publication, 1994, 21 pages.

26. Li, S. C., Libby, P. A. and Williams, F. A., "An Experimental and Theoretical Studies of Spray Impingement on a Hot Surface in Reacting Stagnation Flows," 30th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, Paper Number: AIAA 94-3281, Indianapolis, Indiana, June 27-29, 1994, 18 pages.

27. Li, S. C. and Williams, F. A., "Nitramine Deflagration: A reduced Chemical Mechanism for the Primary Flame," 30th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, Paper Number: AIAA 94-3041, Indianapolis, Indiana, June 27-29, 1994, 10 pages.

28. Lund, K. O., "A Note on Axial-Flow Sensible-Heat Solar-Dynamic Receivers," J. Heat Transfer Vol. 116, Feb., 1994 (pp. 273-275)

29. Lund, K. O., Henschke, G., and Knowles, T. R., "Analysis of Close-Packed Brush-Fiber Thermal Interfaces for Space-Based Thermal Management," 32nd AIAA Aerospace Sciences Meeting, Jan. 1994 Paper No. 94-0450

30. Lund, K. O., "Attenuation Thermal Energy Storage in Sensible-Heat Solar-Dynamic Receivers," Solar Engineering -- 1994, Proc. ASME International Solar Energy Conf., San Francisco, March, 1994 [Accepted].

31. Lund, K. O., "A Direct-Heating Energy-Storage Receiver for Dish/Stirling Solar Energy Systems," Proc. 29th Intersociety Energy Conversion and Engineering Conference, Monterey, CA, August 7-11, 1994 (pp. 1712-1718), AIAA paper no. 94-3944

32. S.S. Penner and A.L. Berlad, "Fundamental Combustion Research in Support of Industrial Applications," Energy – The International Journal, Vol. 20, No. 4, pp. 311-324, (1995).

33. S. Sarkar, "Compressibility Effects on Turbulence Growth in High-Speed Shear Flows," *Applied Mechanics Reviews*, **47**, S179-183 (1994).

34. Yang, B., and Seshadri, K. "The Asymptotic Structure of Methanol-Air Diffusion Flames," Combustion Science and Technology 97, pp. 193-218, 1994.

35. K. Seshadri, N. Peters and F.A. Williams, "Asymptotic Analyses of Stoichiometric and Lean Hydrogen-Air Flames," Combustion and Flame 96, 407-427 (1994).

36. P. Clavin, J.S. Kim and F.A. Williams, "Turbulence-Induced Noise Effects on High-Frequency Combustion Instabilities," Combustion Science and Technology 96, 61-84 (1994).

37. J.M. Card, W.T. Ashurst and F.A. Williams, "Modification of Methane-Air Nonpremixed Flamelets by Vortical Interactions," Combustion and Flame 97, 48-60 (1994).

38. G. Balakrishnan and F.A. Williams, "Turbulent Combustion Regimes for Hypersonic Propulsion Employing Hydrogen-Air Diffusion Flames," Journal of Propulsion and Power 10, 434-437 (1994).

39. P.A. Libby and F.A. Williams, "Fundamental Aspects and Review," Chapter 1 of Turbulent Reacting Flows, (P.A. Libby and F.A. Williams, editors), Academic Press, London, 1994, pp. 1-61.

40. K. Seshadri and F.A. Williams, "Reduced Chemical Systems and Their Application in Turbulent Combustion," Chapter 4 of Turbulent Reacting Flows, (P.A. Libby and F.A. Williams, editors), Academic Press, London, 1994, pp. 153-210.

41. K.N.C. Bray, P.A. Libby and F.A. Williams, "High Speed Turbulent Combustion," Chapter 10 of Turbulent Reacting Flows, (P.A. Libby and F.A. Williams, editors), Academic Press, London, 1994, pp. 609-638.

42. F.A. Williams, "The Next 25 Years of Combustion Theory," Combustion Science and Technology 98, 361-366 (1994).

43. G. Balakrishnan, D. Trees and F.A. Williams, "An Experimental Investigation of Strain-Induced Extinction of Diluted Hydrogen-Air Counterflow Diffusion Flames," Combustion and Flame 98, 123-126 (1994).

44. J.S. Kim and F.A. Williams, "Contribution of Strained Diffusion Flames to Acoustic Pressure Response," Combustion and Flame 98, 279-299 (1994).

45. C. Kennedy, "Bibliography for the Kinetic Theory of Reacting Gases" CECR Report 94-01.

46. A. Liñán and F. A. Williams, "Asymptotic Analyses of n-Heptane Ignition with a Four-Step Kinetic Model" CECR Report 94-02.

47. P. L. García Ybarra, "I. Droplet Vaporization in Supercritical Conditions", and (with A. Sanchez) "II. Multiplicity of Steady States in an Exothermic Reaction-Diffusion Auto Catalytic System" CECR Report 94-03.

9. Numbers of Full Time Employees

The number of full time administrative employees is 2, one university-supported and the other supported on extramural funds.

10. Space

The Center for Energy and Combustion Research occupied these rooms in Engineering Building Unit II: 256, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 570, 571, 576 and 578, and these labs in Engineering Building Unit II: B12, B14, B16 and B17.

CENTER FOR ENERGY AND COMBUSTION RESEARCH

ANNUAL REPORT

July 1, 1993 through June 30, 1994

1. Source of Support:	
CECR/General Fund	36,187
2. Expenditures for administrative support:	
Salaries	26,567
Benefits	8,407
Supplies and Expense	1,483
Equipment	0
Travel	0
TOTAL	36,457
3. Matching Funds:	1,002
4. Research Expenditures:	864,853
5. Indirect Cost Expenditures:	275,633
6. Other Specified Uses:	0

PRINCIPAL INVESTIGATOR	CONTRACT/GRANT NO.	TITLE	PERIOD	1993/1994 AWARD	TOTAL EXPENSE	IDC EXPENSE
Cattolica, R.	NASA NCC2-718	Electron-Beam Fluorescence Methods for Hypersonic Flow Diagnostics	11/01/91 - 06/30/93	0	2,391	291
Lasheras, J.	United Technologies	Turbulent Reacting Flows	06/30/90 - Open	0	10,069	0
Libby, P.	DOE DEFG03-86ER13527	Premixed Turbulent Combustion	06/01/86 - 11/30/94	54,964	51,858	23,825
Libby, P./Williams, F.	DOE DEFG03-87ER13685	Experimental and Theoretical Study of Fuel Droplets Subject to a Straining Flow	05/01/93 - 04/10/95	127,070	65,839	31,981
Libby, P./Williams, F.	NASA NAG 1-1193	Supersonic Mixing Layers Without and With Combustion	10/22/90 - 06/30/94	0	8,794	2,357
Lund, K.	NASA NAG 3-1243	Vapor-Pressure Pumped Heat-Transfer Loop	10/25/91 - 10/24/93	0	84	42
Penner, S.		Energy Research	01/13/84 - Open	0	4,168	0
Penner, S.	DOE DEFG03-93-ER3021	Advanced Fuel Cell Research Needs Assessment	08/01/93 - 12-31-94	339,624	123,195	33,015
Penner, S.	DOE/EG&G Idaho	Fundamental Research in Support of Industrial Combustion Needs	04/04/94 - 11/30/94	11,536	0	0
Seshadri, K.	UERG	Mechanisms of Formation of Benzine in Laminar Counterflow Propane Air Flames	07/01/93 - 06/30/94	24,617	24,449	0
Seshadri, K.	NSF INT 91-14461	U.S.-Federal Republic of Germany Cooperative Res	05/15/92 - 04/30/95	0	5,592	0
Seshadri, K.	NIST 60NANB2D1285	Experimental Studies on the Extinction of Diffusion Flames Using Halon Substitutes	09/01/92 - 08/31/93	60,000	18,384	7,900
Seshadri, K.	NIST 60NANB3D1435	Chemical Inhibition of Methane-Air Diffusion Flames	09/15/93 - 09/15/94	75,000	3,286	3,989
Seshadri, K.	ARO DAAL03-90-G-0084	The Structure of Laminar Flames of CH4/NO2 CH2O/NO2, and HCN/NO2	03/01/90 - 03/31/94	0	13,410	6,339
Williams, F.	NSF CTS 92-14888	Asymptotic Analysis of Flame Structure with Real Chemistry	11/01/92 - 10/31/95	0	65,456	24,945
			Sub-total	692,811	396,975	134,684

PRINCIPAL INVESTIGATOR	CONTRACT/GRANT NO.	TITLE	PERIOD	1993/1994 AWARD	TOTAL EXPENSE	IDC EXPENSE
Williams, F.	AFOSR 91-0130	Fundamentals of Acoustic Instability in Liquid Propellant Rockets of Organic Matter in Southern California Coastal Basins	12/15/92 - 12/14/93	0	59,888	28,201
Williams, F.	AFOSR F49629-93-1-0380	AASERT-92 Theories of Turbulent Combustion in High-Speed Flows	06/01/93 - 05/31/95	0	22,240	515
Williams, F.	NASA NAG3-1081	Scientific Support for a Propossed Space Shuttle Droplet Burning Experiment	01/15/93 - 01/14/95	80,000	57,315	23,352
Williams, F.	NASA NAG3-1248	High-Pressure Combustion of Binary Fuel Droplets	12/15/92 - 12/14/93	0	20,743	10,393
Williams, F.	ONR N00014-94-1-0679	Prediction of NOx Emission from Large Diesels	03/01/94 - 02/28/97	265,000	3,200	1,616
Williams, F.	AFOSR F49620-94-1-0166	Fundamentals of Acoustic Instability in Liquid-Propellant Rockets	02/15/94 - 02/14/95	113,617	40,931	19,697
Williams, F./Li, S.C.	LLNL B264086	Chemical Kinetics of Nitramine Combustion Under Elevated Temperature and Pressure	12/20/93 - 12/31/94	19,000	2,998	2,019
Williams, F./Libby, P.	AFOSR F49620-92-J-0184	Theories of Turbulent Combustion in High Speed Flows	03/01/93 - 02/28/94	135,200	176,341	55,156
Williams, F.		CECR General Funds	07/01/93 - 06/30/94	36,187	36,456	0
Williams, F.		Presidential Chair in Energy & Combustion Research	05/19/93 - Open	41,320	45,149	0
Williams, F.		Catalytic Combustion	01/14/91 - Open	0	412	0
Williams, F.		G A Energy Fellowships	04/20/90 - Open		2,205	0
Williams, F.		Energy Center Conferences	0	0	0	0
			TOTAL	1,383,135	864,853	275,633