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Produced by the NASA Center for Aerospace Information (CASI)
FINAL REPORT

on

NASA GRANT  NSL-05-020-223

for

COLLABORATIVE RESEARCH
IN CARDIOVASCULAR DYNAMICS
AND BONE ELASTICITY

(NASA-CS-142997)  COLLABORATIVE RESEARCH
IN CARDIOVASCULAR DYNAMICS AND BONE
ELASTICITY  Final Report (Stanford Univ.)
10 p  HC $3.25  COIL COLP

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to the

National Aeronautics and Space Administration

by the

Department of Aeronautics and Astronautics

Stanford University
Stanford, California

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October 1974
Under Grant No. NGR/L 05-020-223 the Ames Center of the NASA and Stanford University were engaged in a collaborative research program covering a variety of topics of biomechanics and biomedical engineering within the fields of cardiovascular dynamics, respiration, bone elasticity and vestibular physiology. This cooperative effort has evolved from studies carried out by the principal investigator and Eric Ogden, M.D., Chief of the Environmental Biology Division at Ames, during the former's tenure as a Senior Postdoctoral Resident Research Associate from 1965 to 1967. Since Stanford University did not have the facilities required for interdisciplinary investigations in biomechanics and biomedical engineering, the studies supported by this grant and others were mainly performed within the Ames laboratories, and to this end the Stanford members of the cooperative team were extended guest worker privileges by the Ames Center. The research accomplishments and stimulation that have been generated by this limited pooling of resources and efforts between Stanford University and Ames endorse the recommendation of closer ties between government laboratories and universities made by the Federal Council for Science and Technology*. The goals of the research supported by Grant No. NGR/L 05-020-223 were

1. a better understanding of the mechanical behavior of the circulatory system and its control mechanisms.

2. Development of noninvasive methods of measuring the changes in the mechanical properties of blood vessels and other cardiovascular parameters in man.

3. Application of these noninvasive methods to examine in man the physiological effects of environmental changes, including earth-simulated gravitational changes.

4. Development of in-flight methods for studying the events which lead to post-flight postural hypotension.

Progress made towards these goals had been described in a series of progress-reports and also in 26 full-length publications, 20 short publications, 20 PhD Dissertations and 2 Engineer's theses listed in Appendix I, II and III.

With the appointment of the principal investigator as Professor of Biomedical Engineering at the University of Zurich and Swiss Federal Institute of Technology, Zurich, in October 1971 some of the work, PhD-students and staff were transferred to Switzerland. Thanks to several favorable circumstances including a) the financial support given by the Swiss Federal Government and the Department of Education of the Canton Zurich, b) the loan of NASA laboratory equipment, and c) the close collaboration between the clinical departments of the medical school of the University of Zurich and the Institute of Biomedical Engineering, the projects started under the NASA Grants could on expanded and the human aspects of the research goals much better pursued. As a result of the interdisciplinary efforts in Zurich, we have now in clinical use several prototypes of pulsed ultrasound velocity profile meters which enable us to quantify non-invasively the blood flow in larger arteries and veins of patients with circulatory disorders. Besides this, a new method for measuring changes in the mineral content and cross-section of appendicular bones is now being utilized in the pediatric hospital of the University of Zurich in conjunction with a pilot study of the effects of various therapeutic procedures (including bedrest and inactivity) on calcium metabolism. All data and
information on the research and development work carried out as a continuation of the former Ames projects are available to NASA.

On behalf of Stanford University, the University of Zurich, the Swiss Federal Institute of Technology in Zurich and the students and faculty associated with the projects supported by NASA Grant NGR/L 05-020-223 I wish to express our sincere thanks for the opportunity to partake in NASA's research and development programs.

A final budgetary statement on Grant NGR/L 05-020-223 is given in Appendix IV.
APPENDIX I

FULL-LENGTH PUBLICATIONS


5. "Dispersion and Attenuation of Small Artificial Pressure Waves in the Canine Aorta" (co-authors M. Histand and E. Ogden), Circulation Research, Vol. XXIII, October, pp 539-551 (1968)


APPENDIX II

SHORT PUBLICATIONS


7. "Effects of Pressure on Dispersion and Attenuation of Waves in the Aorta" (co-author E. Ogden), Invited Paper, Digest of 7th International Conference on Medical and Biological Engineering, Stockholm, Sweden, August 14-19, p. 149 (1967)


26. "Mechanical Properties of Intact Bones" (co-authors M. Farshad, G. Thompson and D. Young), Digest of the 9th International Conference on Medical and Biological Engineering, Melbourne, Australia, p. 157, (1971)

27. "A Multiple Gate Pulse Doppler Flowmeter" (co-author F.D. McLeod), IEEE Ultrasonics Symposium, Miami Beach, Florida, December, p. 51 (1971)

28. "A Nonlinear Model of a Viscoelastic Arterial System" (co-author R.L. Rockwell), 3rd Annual Meeting of the Biomedical Engineering Society, Baltimore, Maryland, April 7 & 8, No. 75 (1972)
APPENDIX III

A. PH.D. DISSERTATIONS ASSOCIATED WITH NASA GRANT NGR/L 05-020-223

1. James A. Maxwell  June 1967
   "The Dispersion and Dissipation of Waves in Blood Vessels"

2. Everett Jones  June 1968
   "Effects of Viscosity and External Constants on Wave Transmission in Blood Vessels"

   "Theoretical Model Studies of Wave Propagation in the Semicircular Canals"

4. Michael B. Histand  April 1969
   "An Experimental Study of the Transmission Characteristics of Pressure Waves in the Aorta"

5. Michael K. Wells  April 1969
   "On the Determination of the Elastic Properties of Blood Vessels from their Wave Transmission Characteristics"

   "Transmission Characteristics of Distension, Torsion and Axial Waves in Arteries"

   "Theoretical Studies on High Frequency Wave Propagation in Blood Vessels"

   "Nonlinear Analysis of Pressure- and Shock Waves in Blood Vessels"

   "Experimental Studies of the Variations in the Mechanical Properties of the Canine Abdominal Vena Cava"
10. William C. Van Buskirk
   April 1970
   "Experimental and Theoretical Model
   Studies of Some Dynamic Response Character-istics of the Semicircular Canals"

11. Po Kee Wong
   June 1970
   "Waves in Viscous Fluids, Elastic Solids, and Viscoelastic Materials"

12. William Frank Bozich
   Sept. 1970
   "Wave Propagation in Simple Nonhomo-
   geneous Systems with a Transition Point"

13. Mehdi Farshad
   April 1971
   "Mathematical Models for the Electromecha-
   nical Behavior of Intact Bones"

14. Richard S. Chadwick
   June 1971
   "Light Scattering from Blood Cells in
   a Shear Flow"

15. Fortunato Orti-Daras
   June 1971
   "Investigation of Wave Propagation in
   Curved Elastic Tube Filled with Vis-
   cous Fluid"

16. William R. Powell
   June 1971
   "Experimental and Theoretical Studies of
   the Lung as an Elastic Structure"

17. Gerald A. Thompson
   Sept. 1971
   "Experimental Studies of Lateral and Tor-
   sional Vibrations of Intact Dog Radii"

18. Phillip J. Bendick
   April 1973
   "A Laser Doppler Study of Velocity Profiles
   in Oscillatory Flow"

19. Kirk J. Bundy
   Dec. 1974
   "Experimental Studies of the Anisotropy
   and Nonuniformity of Compact Bone from
   Human Femurs"

20. Doran R. Klingler
    Dec. 1974
    "Techniques of Measuring the Propagation
    of Pressure Waves in the Microcirculation"
1. William J. Astleford  
Dec. 1968

"Direct Determination of Distensibility of the Left Ventricle of the Heart under In Vivo Conditions"

2. Li-Ko Chang  
June 1970

"An Analytic Study of the Transmission of Pulse Wave in Tapered Vessels"
GRANTS

Final-Cumulative Cost Expenditure Report

1. Cumulative Award................. 562,486.00
2. Cumulative Costs.................. 562,486.00
   (a) Balance.......................... 0
3. Cost Sharing....................... 14,572.30

I certify that all expenditures reported (or payments requested) are for appropriate purposes and in accordance with the agreements set forth in the application and award documents.

Signed by an Authorized Official of the University
Expenditure Control Manager

Date 11-21-74