

**REPORT DOCUMENTATION PAGE**

AFRL-SR-BL-TR-01-

The public reporting burden for this collection of information is estimated to average 1 hour per response, including gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments and suggestions for reducing the burden, to Department of Defense, Washington Head Office (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB Control Number.  
**PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

Unrecorded, unclassified Reports shall be

0524

<b>1. REPORT DATE (DD-MM-YYYY)</b> 31-08-2001		<b>2. REPORT TYPE</b> Final		<b>3. DATES COVERED (From - to)</b> 1 Sept. 97 -- 31 Aug. 01	
<b>4. TITLE AND SUBTITLE</b>  Data assimilation for thermospheric Forecasting with application to satellite ephemeris prediction				<b>5a. CONTRACT NUMBER</b> F49620-97-1-0447	
				<b>5b. GRANT NUMBER</b>	
				<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>  Jeffrey M. Forbes, Professor				<b>5d. PROJECT NUMBER</b>	
				<b>5e. TASK NUMBER</b>	
				<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> University of Colorado Department of Aerospace Engineering Sciences				<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>	
<b>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> AFOSR/NM 801 N. Randolph Street ~ Room 732 Arlington, VA 22203-1977				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>	
				<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION/AVAILABILITY STATEMENT</b>  Unlimited unclassified				AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFOSR) NOTICE OF TRANSMITTAL DTIC. THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLIC RELEASE LAW AER 100-12. DISTRIBUTION IS UNLIMITED.	
<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b>  Climotological density patterns derived from low-orbit accelerometer data are shown to be consistent with meridional advection of disturbances originating at high latitudes. Long-term (11 year) and short-term (daily and 27-day) variations in thermospheric density are delivered in terms of the MG II solar index.					
<b>15. SUBJECT TERMS</b>  Satellite drag, thermospheric density, accelerometer, ephemeris					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b>
a. REPORT	b. ABSTRACT	c. THIS PAGE			<b>19b. TELEPHONE NUMBER (Include area code)</b>
U	U	U	UU	2	

20011012 022

**FORM A1-2**  
**AUGMENTATION AWARDS FOR SCIENCE & ENGINEERING**  
**RESEARCH TRAINING (ASSERT)**  
**REPORTING FORM**

The Department of Defense (DOD) requires certain information to evaluate the effectiveness of the AASERT program. By accepting this Grant Modification, which bestows the AASERT funds, the Grantee agrees to provide the information requested below to the Government's technical point of contact by each annual anniversary of the ASSERT award date.

1. Grantee identification data: *(R & T and Grant numbers found on Page 1 of Grant)*

a. THE REGENTS OF THE UNIVERSITY OF COLORADO

University Name  
b. F49620\_97-1-0447

c. Not known

Grant Number  
d. Jeffrey Forbes,

PR Number  
e. From: 1 Sept. 97 To: 31 Aug. 01

P.I. Name

AASERT Reporting Period

**NOTE: Grant to which AASERT award is attached is referred to hereafter as "Parent Agreement."**

2. Total funding of the Parent Agreement and the number of full-time equivalent graduate students (FTEGS) supported by the Parent Agreement during the 12-month period prior to the AASERT award date.

a. Funding: \$ 205,000

b. Number FTEGS: 0.5

3. Total funding of the Parent Agreement and the number of FTEGS supported by the Parent Agreement during the current 12-month reporting period.

a. Funding: \$ 0

b. Number FTEGS: 0

4. Total AASERT funding and the number of FTEGS and undergraduate students (UGS) supported by AASERT funds during the current 12-month reporting period.

a. Funding: \$ 13,200

b. Number FTEGS: 1

c. Number UGS: 0

**VERIFICATION STATEMENT:** I hereby verify that all students supported by the AASERT award are U.S. citizens.

Principal Investigator

Date

GRANT NUMBER: N00014-97-1-0766

## FINAL REPORT

### **AASERT97 - Data Assimilation for Thermospheric Density Forecasting, with Application to Satellite Ephemeris Prediction F49620-97-1-0447**

**Jeffrey M. Forbes, Principal Investigator  
University of Colorado**

**1 Sept 01**

**Objectives:** The research seeks to (1) better understand, specify and forecast the global structure of upper atmosphere density, and other parameters, through assimilation of observational data (mostly satellite drag) into models; and (2) improve upon existing capabilities to predict satellite orbits.

**Summary of Findings:** During the first two years of support, Mr. Rhoden extracted the geomagnetic density variation in low earth orbit from satellite accelerometer measurements, and showed how the climatological patterns are consistent with meridional advection of disturbances originating at high latitudes. He also delineated both the long-term (11-year) and short-term (daily and 27-day) variations in thermospheric density in terms of the Mg II solar index. Both of these results will play an important role in the development of future empirical models of atmospheric drag.

During the past year, and ongoing, Mr. Rhoden has expanded the earlier analysis to include comparisons with Jacchia 1970 (J70) model density trends in addition to the published MSISE-90 comparisons. He has also incorporated a short-term least squares fit analysis into those codes in order to develop an overall least squares model of the combined long- and short-term solar variabilities in the SETA density residuals. In addition, Mr. Rhoden has collected and preprocessed satellite data for approximately 20 satellites, including observations and element sets. This data is used in conjunction with special perturbation codes (SPDC and SPEPH) and the generation of satellite reference and predicted orbits necessary in the analysis of improvements in orbit prediction accuracies. These orbit prediction techniques are consistent with those used by USSPACECOM and AF/SWC. In fulfillment of University of Colorado requirements for the Ph.D. program, Mr. Rhoden's dissertation committee was formed and a comprehensive proposal was presented to his committee detailing future proposed activities and desired goals for his research project.

**Personnel:** This grant supported in part the Ph.D. Dissertation research of Mr. Eric Rhoden, Ph.D. Candidate in the Department of Aerospace Engineering Sciences. Mr. Rhoden is still in the process of completing his Dissertation requirement.

**Publications:** Rhoden, E.A., J.M. Forbes, and F.A. Marcos, The influences of geomagnetic and solar variabilities on lower thermosphere density, J. Atmos. Solar-Terr. Phys., 62, 999-1013, 2000.

**Interactions/Transitions (Papers presented by Mr. Rhoden):**

Poster presentation -- AFOSR Meeting, March 1999, Data Assimilation for Thermospheric Density Forecasting, with Application to Satellite Ephemeris Prediction (F49620-97-1-0447), Jeffrey M. Forbes and Eric A. Rhoden, University of Colorado, Boulder, CO.

Poster presentation -- 1999 Spring AGU, June 1999, Geomagnetic and Solar Variabilities in Thermospheric Density, E.A. Rhoden (1), J.M. Forbes (1), F.A. Marcos (2); (1) University of Colorado, Boulder, CO; (2) Air Force Research Laboratory, Hanscom AFB, MA.

Poster presentation -- 1999 CEDAR, June 1999, Geomagnetic and Solar Variabilities in Thermospheric Density, E.A. Rhoden (1), J.M. Forbes (1), F.A. Marcos (2); (1) University of Colorado, Boulder, CO; (2) Air Force Research Laboratory, Hanscom AFB, MA.

Comprehensive Exam Report and Presentation -- Improved Modeling of Thermospheric Density Perturbations with Application to Satellite Ephemeris Prediction, Eric Rhoden, December 2000.

Attended -- 1999 AAS/AIAA Astrodynamics Specialist Conference (attendee), August 16-18, 1999, Girdwood, AK.

**New discoveries, inventions, patents:** None

**Honors/Awards:** 3rd place, Best Student Poster Award, Annual CEDAR Meeting, Boulder, CO, June, 1999.