GODDARD EARTH SCIENCES AND TECHNOLOGY CENTER

Quarterly Report
Cooperative Agreement NCC5-494
Reporting Period: April 1, 2002 through June 30, 2002

Goddard Earth Sciences and Technology Center
University of Maryland, Baltimore County
1000 Hilltop Circle
Baltimore, MD 21250

UMBC
AN HONORS UNIVERSITY IN MARYLAND
Quarterly Report
Cooperative Agreement NCC5-494
The Goddard Earth Sciences and Technology Center
Reporting Period: April 1, 2002 through June 30, 2002

Goddard Earth Sciences and Technology Center
University of Maryland, Baltimore County
1000 Hilltop Circle
Baltimore, MD 21250
Technical Status Report

The following is a technical report of the progress made under Cooperative Agreement NCC5-494, the Goddard Earth Sciences and Technology Center (GEST). The period covered by this report is April 1, 2002 through June 30, 2002.

Overview of significant Activities

GEST celebrated another year in operation on May 11, 2002. We are now Two Years Old. Since establishing GEST, more than 120 faculty and support staff members have been hired into the organization.

Significant progress has been made in this second year in establishing GEST as a prominent center for research and international collaboration in the Earth and information sciences. The breadth of research interest has also grown, allowing the formation of five Research Group Leaders.

The Goddard Visiting Fellows Program in the Earth Sciences continued into its second year. This program provides the opportunity for selected Ph.D. scientists to pursue independent research in collaboration with scientists in the laboratories within the Earth Sciences Directorate either at the Goddard Space Flight Center or at the Goddard Institute for Space Studies.

During this second year, we added a permanent GEST researcher who is a faculty member at Hampton University, collaborating in oceanographic biology studies at the Wallops flight facility; a researcher on the faculty of Howard University joined GEST to collaborate in study of atmospheric aerosols. Here are now several Caelum Research Scientists on the GEST scientific staff, and Caelum continues to provide the administrative support required by the Education and Visiting Scientists programs. Northrop Grumman has provided invaluable advice and support through representation on the GEST Executive Board, and plans to participate in this summer’s new Coastal Research Fellowship program through mentoring and instrumentation support.

SUMMER PROGRAMS – GSSP Seminar Series

Climate Change and the Global Water Cycle

Visitors Center Auditorium, NASA Goddard Space Flight Center, Greenbelt, MD

In conjunction with the 2002 Graduate Student Summer Program in Earth System Science, the Goddard Earth Sciences and Technology Center (GEST) and the Earth Sciences Directorate of the Goddard Space Flight Center (GSFC) organized the second lecture series to be held June 11-14, 2002. The intent of this series was to promote the understanding of current scientific knowledge about the challenges of global change, and how NASA supports the research underpinning this knowledge. Featured speakers and topics are listed below:
Tuesday June 11

9:00 am Welcome
Mark Schoeberl, GSFC

9:10 am Global Water and Energy Cycle:

NASA plans to address key uncertainties.

Robert Schiffer, GEST

10:30 am Water vapor, clouds, and the Earth radiant energy balance.

William Collins, NCAR

1:30 pm Climate change and expected impacts on the global water cycle.

David Rind, GISS

2:50 pm Global precipitation: observations, historical records, and trends.

Bob Adler, GSFC

Wednesday June 12

9:00 am Welcome
Robert Curran, GEST

9:10 am Relationships between weather extremes, climate variability and long-term trends.

Wayne Higgins, NOAA

10:30 am Predictability of seasonal weather and precipitation patterns.

Randy Koster, GSFC

1:30 pm Severe hydrologic events: predictability and trends projection.

Harry Lins, USGS

2:50 pm Quantitative precipitation forecasts: prospects and outstanding science challenges.

Chris Kummerow, Colorado State University

Thursday June 13:

9:00 am Welcome
Tom Low, GEST

9:10 am Multi-scale cloud system simulation, dynamics and transport.

Mitchell Moncrieff, NCAR

10:30 am Ocean-atmosphere fluxes: surface interaction, PBL transport, and the role of moist convection.

Mark Helfand, GSFC

1:30 pm Land-atmosphere fluxes: evaporation, soil moisture, and run-off: observation and modeling.

Matt Rodell, GSFC

2:50 pm Land surface and hydrologic observations.

Christa Peters-Lidard, GSFC
Friday June 14:  

Water Resources and Hydrologic Applications

9:00 am Welcome  
Robert Schiffer, GEST

9:10 am Hydrologic modeling and prediction systems.  
Guido Salvucci, Boston University

10:30 am Dealing with spatial variability in landscape, soil, and hydrologic variables.  
Dennis Lettenmaier, University of Washington

1:30 pm Evapotranspiration and its estimation with satellite data.  
Thomas Schmugge, USDA

2:50 pm Impacts of water system management and human demand on water resources.  
Soroosh Sorooshian, University of Arizona

Research Milestones for the Reporting Period

GEST hosted this year’s SPARC DA Workshop at UMBC Campus from Monday - Wednesday, June 10-12, 2002. A reception was held on Monday evening to formerly welcome all participants to the UMBC campus.

Topic outlines and speakers are listed below:

Monday - June 10th

Exploitation of ESA Atmospheric EO Measurements through Assimilation Techniques – Claus Zehner

Intercomparison of DATA Assimilation Products in the Polar Winter Stratopshere - Gloria Manney

Stratospheric Data Assimilation at the Met Office - Richard Swinbank

Meteorological analyses in the DAO: operational and reanalysis products – Steven Pawson

Sensitivity of middle atmospheric analyses to the representation of gravity-wave drag in the DAO’s data assimilation system - Shuhua Li

On the extended stratospheric version of the 3D-Var/GEM model of the CMC/MRB using a new hybrid vertical coordinate - Sandrine Edouard

Recent developments in data assimilation system for the Canadian Middle Atmosphere Model (CMAM) - Saroja Polavarapu
Tuesday—June 11th—Topics

Reconstruction of Stratospheric Ozone Fields using Equivalent Latitude Mapping - Cora Randall

Global 3-D Ozone Estimation Using TOMS Column Ozone and Equivalent Latitude - Douglas Allen

An Overview of the SBUV/2 Operational and Reprocessed Ozone Data - Shobha Kondragunta

Use of 3D Global Ozone Fields to Simulate Satellite Data for Testing Data Assimilation and Inversion Algorithms - John Hornstein

Assimilation of ozone data in the ECMWF assimilation system - Antje Dethof

Ozone Assimilation at the Data Assimilation Office - Ivanka Stajner

Ozone assimilation at the Met Office - David Jackson

GOME ozone data assimilation and ozone forecasting at the KNMI - Henk Eskes

Ozone assimilation system with coupled GCM and CTM developed at MRI/JMA - Toru Sasaki

An ozone assimilation strategy using SBUV radiances - Pawan K. Bhartia

Wednesday—June 12th—Topics

Assimilation of Envisat data at DARC - William Lahoz

4D-var assimilation of satellite data: uniqueness tests and CRISTA data assimilation - Hendrik Elbern

Towards operational chemical data assimilation at BIRA-IASB: BASCO - Dominique Fonteyn

An Overview of constituent assimilation efforts at NCAR, ACD - Jean-Francois Lamarque

Using Data Assimilation for Scientific Assessment of Atmospheric Chemistry - David Lary
GEST Faculty and Staff

GEST Administrative Staff

Two administrative staff members were hired during this reporting period, Dr. Robert Schiffer, GEST Chief Scientist, and Dr. Tom Low, GEST Associate Director. Dr. Low was formerly Manager, Applied Sciences and Lead contact with our consortium member Caelum Research Corporation. Dr. Robert Schiffer’s background is in Atmospheric Sciences and Climate Research.

Contact information of each of the GEST administrative staff members are given in Appendix T-2 following this technical report.

GEST Technical Staff

The GEST Council has two new members, Tom Low and Robert Schiffer. A complete list of members of the GEST Council are noted in Table T-1 below.

Table T-1 GEST Council Members

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Code</th>
<th>Section</th>
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<tbody>
<tr>
<td>Robert Curran</td>
<td>Director</td>
<td>900</td>
<td>Administration</td>
</tr>
<tr>
<td>Tom Low</td>
<td>Associate Director</td>
<td>900</td>
<td>&quot;</td>
</tr>
<tr>
<td>L. Anathea Brooks</td>
<td>Assistant Director</td>
<td>900</td>
<td>&quot;</td>
</tr>
<tr>
<td>Robert Schiffer</td>
<td>Chief Scientist</td>
<td>900</td>
<td>&quot;</td>
</tr>
<tr>
<td>Dr. Julio Bacmeister</td>
<td>Faculty Group Leader</td>
<td>971</td>
<td>Seasonal and Interannual Prediction</td>
</tr>
<tr>
<td>Dr. Susan Hoban</td>
<td>Faculty Group Leader</td>
<td>103</td>
<td>Information Science and Technology</td>
</tr>
<tr>
<td>Dr. Steven Pawson</td>
<td>Faculty Group Leader</td>
<td>910</td>
<td>Climate and Trace Species</td>
</tr>
<tr>
<td>Dr. Susan Sakimoto</td>
<td>Faculty Group Leader</td>
<td>921</td>
<td>Land Surface and Hydrology</td>
</tr>
<tr>
<td>Dr. Alexander Smirnov</td>
<td>Faculty Group Leader</td>
<td>923</td>
<td>Aerosols and Clouds</td>
</tr>
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</table>

Position advertisements appeared in EOS and Science. Information concerning these advertisements is provided in Table T-2.
Table T-2  Position advertisements published during this reporting period

<table>
<thead>
<tr>
<th>Advertisement</th>
<th>No. of Positions</th>
<th>Publication Date</th>
<th>Closing Date</th>
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<td>4/30/02</td>
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<tr>
<td>Science</td>
<td>2</td>
<td>4/02</td>
<td>4/30/02</td>
</tr>
<tr>
<td>The Chronological of</td>
<td>1</td>
<td>4/02</td>
<td>5/15/02</td>
</tr>
<tr>
<td>Higher Education</td>
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Changes in the GEST technical staff during this reporting period are provided in the following two tables, Table T-3 and Table T-4.

Table T-3 GEST technical and administrative staff hired during the reporting period

<table>
<thead>
<tr>
<th>Name</th>
<th>Sponsor</th>
<th>Code</th>
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</thead>
<tbody>
<tr>
<td>Mircea Grecu</td>
<td>Bob Adler</td>
<td>912</td>
</tr>
<tr>
<td>Hiro Hayashi</td>
<td>Steven Pawson</td>
<td>910</td>
</tr>
<tr>
<td>Daniel Jacob</td>
<td>C. Koblinsky</td>
<td>971</td>
</tr>
<tr>
<td>Lyapustin, Alexei</td>
<td>Robert Murphy</td>
<td>920</td>
</tr>
<tr>
<td>Tom Low</td>
<td>GEST Associate Director</td>
<td>900</td>
</tr>
<tr>
<td>Robert Schiffer</td>
<td>GEST Chief Scientist</td>
<td>900</td>
</tr>
<tr>
<td>Xiping Zeng</td>
<td>Bob Adler</td>
<td>912</td>
</tr>
</tbody>
</table>

Table T-4 GEST technical staff who have left during the present reporting period

<table>
<thead>
<tr>
<th>Name</th>
<th>Sponsor</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jiayu Zhou</td>
<td>William K. Lau</td>
<td>913</td>
</tr>
</tbody>
</table>

The subsequent positions that this individual went to is as follows: (J. Z.) NOAA National Weather Service Headquarters.

At the end of the reporting period GEST had approximately 100 research staff on board.

Submitted or Published Papers by GEST Researchers During this Reporting Period

The articles submitted or published during this reporting period are listed in the Appendix T-2 at the end this section of the report.
GEST Related Seminars for this Reporting Period

Several GEST related seminars are listed in Appendix T-3 at the end of this section of the report.

Proposals Submitted by GEST Researchers During this Reporting Period

Proposals submitted by UMBC GEST research faculty are listed in Appendix T-4 at the end of this section of the report.
Appendix T-1. GEST Administrative Staff

GEST Administrative Staff as of June 30, 2002.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Location</th>
<th>Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robert J. Curran</td>
<td>Director</td>
<td>UMBC/GSFC</td>
<td>410-455-8813</td>
</tr>
<tr>
<td></td>
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<td>301-286-4403</td>
</tr>
<tr>
<td>Tom Low</td>
<td>Associate Director</td>
<td>UMBC/GSFC</td>
<td>410-455-8814</td>
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<tr>
<td></td>
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<td></td>
<td>301-286-4403</td>
</tr>
<tr>
<td>L. Anathea Brooks</td>
<td>Assistant Director</td>
<td>UMBC/GSFC</td>
<td>301-286-4226</td>
</tr>
<tr>
<td>Robert Schiffer</td>
<td>Chief Scientist</td>
<td>GSFC</td>
<td>410-455-8810</td>
</tr>
<tr>
<td>Debbie Hicks</td>
<td>Business Manager</td>
<td>UMBC</td>
<td>410-455-8815</td>
</tr>
<tr>
<td>Grace Roscoe</td>
<td>Executive Assistant</td>
<td>UMBC</td>
<td>410-455-8808</td>
</tr>
<tr>
<td>Nancy Flowers</td>
<td>Administrative Assistant II</td>
<td>UMBC</td>
<td>410-455-8899</td>
</tr>
<tr>
<td>Cherrie Johnson</td>
<td>Administrative Assistant II</td>
<td>GSFC</td>
<td>301-286-4403</td>
</tr>
<tr>
<td>Deborah Belvedere</td>
<td>Program Assistant</td>
<td>GSFC</td>
<td>301-614-5809</td>
</tr>
<tr>
<td>Arlene Rustmann</td>
<td>Program Assistant</td>
<td>GSFC</td>
<td>301-614-5733</td>
</tr>
<tr>
<td>Frances Lilly</td>
<td>Visitor/School Coordinator</td>
<td>GSFC</td>
<td>301-286-4099</td>
</tr>
<tr>
<td>Denise Everhart</td>
<td>Student Support</td>
<td>GSFC</td>
<td>301-286-4099</td>
</tr>
</tbody>
</table>

Locations:

**UMBC**
UMBC Technology Center, South Campus
1450 S. Rolling Road, Suite 3.002
Baltimore, MD 21227

**GSFC**
NASA Goddard Space Flight Center
Mail Code 900.1
Bldg, 28, Room W223
Greenbelt, MD 20771
Appendix T-2. PUBLICATIONS, April 1, 2002 –June 30, 2002

Refereed

Paul Ginoux


Randall V. Martin 1, Daniel J. Jacob 1, Robert M. Yantosca 1, Mian Chin 2,3, Paul Ginoux, Global and regional decreases in Tropospheric oxidants from photochemical effects of aerosols, submitted to JGR, June 2002.


Shuhua Li

Judit Pap
SOLAR IRRADIANCE VARIATIONS OVER SOLAR CYCLES 21 TO 23, J. M. Pap (Goddard Earth Sciences and Technology Center, UMBC), J. Kuhn (Institute of Astronomy, University of Hawaii), H. Jones (NASA Goddard Space Flight Center, Southwestern Station/NSO), M. Turmon (Jet Propulsion Laboratory), N. Arge (NOAA Space Environment Center), W. Schmutz (World Radiation Center, PMOD), L. Floyd Interferometrics Inc., NRL.

Oreste Reale

Joan Rosenfield


Chung-Lin Shie


Chaojiao Sun


Xiwu Zhan

Appendix T-3. SEMINARS, April 1, 2002 - June 30, 2002

Alexander M. Chekalyuk

Tom Eck


Charles Gatebe


Gail Skofronick-Jackson

Judit Pap

Zhaoxia Pu
Pu, Zhaoxia, W.-K. Tao, and W. Olson, 2002: Mesoscale Assimilation of TRMM Data with 4DVAR. 5th Workshop on Application of Adjoint in Meteorology, April 21-26, 2002, Mount Bethel, PA.
Pu, Zhaoxia, Applications of Data Assimilation in Improving Atmospheric Modeling. Rutgers University, April 16, 2002.

Rolf Reichle


Susan Strahan
American Geophysical Union in Washington DC, S.E. Strahan, "Influence of Planetary Wave Transport on Arctic Ozone as Observed by POAM III" - May 28, 2002. NASA/GSFC web site 5/28/02 - "A warm polar winter was easier on Arctic ozone."

Song Yang
Appendix T-4.
Proposals Submitted & Funded – April 1, 2002 - June 30, 2002

P.I: Gail Jacson - funded
Title: "Deriving Microphysical Cloud Profiles using Airborne Active and Wideband Passive Microwave Observations"
Sponsoring Agency: NASA
Budget/Commitment $78,175

P.I: Wenge Ni-Meister - funded
Title: "The Effect of Subgrid Variability of Snow Cover in Vegetated Regions on Land-Atmosphere Interactions"
Sponsoring Agency: NASA
Budget/Commitment $65,000

P.I: Judit Pap - funded
Title: "Study of Solar and Spectral Variations Based on SOHO/ VIRGO and MDI"
Sponsoring Agency: NASA
Budget/Commitment $136,748

P.I: Judit Pap - funded
Title: "The Study of the Terrestrial Effects of Solar Irradiance Variations from EUV to Infrared: A New Approach"
Sponsoring Agency: NASA
Budget/Commitment $66,614

P.I: Steven Pawson - funded
Title: "Reanalysis for Stratospheric Trace Gas Studies (RESTS)"
Sponsoring Agency: NASA
Budget/Commitment $142,235
PI:          Song Yang - funded
Title:      "Improvement of General Circulation Model Simulation Using
Sponsoring Agency:  Global Observations of Precipitation/Laten"
Budget/Commitment:  NASA
                           $67,178
Business Status Report

Amendments Received During this Reporting Period

Four amendments to the Cooperative Agreement were received during the present reporting period. At the start of the reporting period a total of $14,795,729 was obligated to the Cooperative Agreement. As of 6/30/02 the total financial obligation was $17,496,236. Table B.1 gives an overview of these amendments.

Table B.1. Amendments to NCC5-494, received between 4/1/02 and 6/30/02.

<table>
<thead>
<tr>
<th>Amendment Number</th>
<th>Date</th>
<th>Amount</th>
<th>Activities Added/Augmented</th>
<th>Activities Deleted</th>
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<td>34</td>
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The attached Table B.2 gives a detailed breakdown of the new or augmented activities in amendments 31, 32, 33, and 34.

Summary of Account Activity

The most recent cost analysis for GEST, giving actual costs accrued during the reporting period was dated 6/30/02. Table B.3 gives a detailed breakdown, by task number of the costs incurred, the approved budget and remaining balance, during the reporting period.
<table>
<thead>
<tr>
<th>A</th>
<th>U</th>
<th>L</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Approved</th>
<th>Budget</th>
<th>Projected</th>
<th>Balance</th>
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<td>4/1/02-6/30/02 (thru 3/31/01)</td>
<td>Year to Date</td>
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<td>as of 6/30/02</td>
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</tbody>
</table>

**Summary:**
- The table outlines detailed cost breakdowns for the last three months of reporting.
- Each row represents a different task or sponsor with columns for salary, fringe, travel, subcontract, supplies, publications, equipment, ODC, direct costs, indirect costs, costs, costs, total costs, approved budget, and projected balance.
- The data spans from 4/1/02 to 6/30/02, with year-to-date figures until 7/1/01 and 6/30/02.
<table>
<thead>
<tr>
<th>A</th>
<th>C</th>
<th>T</th>
<th>U</th>
<th>A</th>
<th>I</th>
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<th>Total</th>
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<th>Approved</th>
<th>Projected</th>
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<tbody>
<tr>
<td>Salary</td>
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<td>Supplies</td>
<td>Publications</td>
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<td>Equipment</td>
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<tr>
<td>18,219</td>
<td>2,372</td>
<td>908</td>
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<td>20,323</td>
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<td>18,219</td>
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<td>0</td>
<td>20,323</td>
<td>6,196</td>
<td>26,519</td>
</tr>
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</table>

**TABLE 3:** Detailed Cost Breakdown for the Last Three Months of the Reporting Period

| GEST Month Long Analyses - April 1, 2002 - June 30, 2002 |

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
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<td>06-15-02</td>
<td>Total</td>
<td>12,000</td>
</tr>
</tbody>
</table>

**Table Notes:**
- **Direct Costs:** Amounts directly attributable to the project.
- **Indirect Costs:** Overhead costs not directly attributable to the project.
- **Costs:** Total of Direct and Indirect Costs.
- **Remaining:** Total Costs minus Approved Costs.
**TABLE B-3: DETAILED COST BREAKDOWN FOR THE LAST THREE MONTHS OF THE REPORTING PERIOD**

**GEST Task Fund Sponsor** | **A** | **C** | **T** | **U** | **A** | **L** | **OHC** | **Direct Costs** | **Indirect Costs** | **Total** | **Total** | **Approved** | **Projected** | **Balance** |
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
**Salary** | **Travel** | **Subsistence** | **Supplies** | **Publications** | **Contractual** | **Equipment** | **Total** | **Total** | **Budget** | **Costs** | **Remaining** |

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<th>6/30/02</th>
<th>Year to Date</th>
<th>4/30/02-6/30/02</th>
<th>Totals</th>
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**Totals** | 1,494,188 | 209,776 | 169,012 | 0 | 208 | 0 | 1,563 | 1,500 | 2,246 | 1,923,419 | 654,287 | 2,577,706 | 10,107,298 | 12,514,004 | 17,496,236 | 0 | 5,069,008
STAGE SEPARATION PERFORMANCE DYNAMIC ANALYSIS

Progress Report

Order Number: NAS8-02058

Prepared for

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

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J. Liu

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December 1, 2002
STAGE SEPARATION PERFORMANCE DYNAMIC ANALYSIS

OBJECTIVES

Stage separation process is an important phenomenon in multi-stage launch vehicle operation. The transient flowfield coupled with the multi-body systems is a challenging problem in design analysis. The thermodynamics environment with burning propellants during the upper-stage engine start in the separation processes adds to the complexity of the entire system. Understanding the underlying flow physics and vehicle dynamics during stage separation is required in designing a multi-stage launch vehicle with good flight performance. A computational fluid dynamics model with the capability to coupling transient multi-body dynamics systems will be a useful tool for simulating the effects of transient flowfield, plume/jet heating and vehicle dynamics. A computational model using generalize mesh system will be used as the basis of this development. The multi-body dynamics system will be solved, by integrating a system of six-degree-of-freedom equations of motion with high accuracy. Multi-body mesh system and their interactions are modeled using parallel computing algorithms. Dynamic stage separation CFD model will be developed with multiple-body detaching mechanism, body contact detection method and plume impingement heating effects modeled. The following tasks are proposed to accomplish the technical objectives.

TASKS ACCOMPLISHED IN THIS REPORTING PERIOD

Isolated LGBB Aerodynamics Analysis

Computations and data analyses of the LGBB isolated vehicle configuration have been performed. A new grid is generated to include a single vehicle in a domain representing the wind tunnel. The total number of elements for this case is 410,569. The freestream velocity, pressure and temperature are 645.95 m/s, 0.065879 ATM and 116.1403 K respectively. This gives the freestream Mach number of 2.99. A baseline case with zero angles of attack is analyzed. Subsequent cases were then computed with 2 degrees increment in angles of attack. A total of 12 cases for angles of attack from -4 degrees to 18 degrees were solved. The clustered PC computer system, chimaera, of NASA/MSFC is provided to test the parallel computational performance. Five computer nodes with total of 10 processors were used for the computations. This provides a very quick turnaround for each case. The baseline (zero angles of attack) case took 5000 time steps to get a converged solution, which took about 5 hours wall clock time to complete. A converged solution is obtained when the integrated normal and axial forces reached steady-state values. Each subsequent cases with angles of attack increment of decrement took another 3000 time steps (or 3 hours wall clock time) to complete. Therefore, all 12 cases were solved within 3
working days. This reveals the power of the clustered PC system for doing real engineering analysis using the present CFD model.

The integrated normal force, axial force and pitching moment coefficients are collected and plotted against the measured data from the wind tunnel tests conducted at NASA/MSFC. Figures 1 to 3 show the results of data comparisons. It is clear that the present model gives good agreements between predicted and measured normal and axial force coefficients. Comparisons in pitching moment coefficients also show good agreements for angles of attack less than 8 degrees. Discrepancies for higher angles of attack cases are unclear at this moment. The leveling off in the measured pitching moment for angles of attack higher than 8 degrees indicates the possibility of flow separation (or vortex breakdown) along the wing upper surface. However, the CN curve does not give such indication.

To resolve the issue of data discrepancies in pitching moment coefficients, adaptive mesh cases will be analyzed to reveal more information about the flowfield for high angles of attack conditions.

![Graph of Stage Separation - Single Vehicle Test Cases (Isolated)](image)

Figure 2. Comparisons of normal force coefficients.
Figure 2. Comparisons of axial force coefficients.

Figure 3. Comparisons of pitching moment coefficients.
Dynamic Chimera Grid Model Development

The development of a general methodology for simulating dynamic stage separation configuration using overset grid systems is continued in this reporting period. The basic database for handling the interpolation procedures among systems of overset grid is under construction. Procedure optimization and overall process efficiency is the major concern for good computational speed and solution robustness in the long run. Following the database construction, the performance of the general interpolation procedure will be tested and fine-tuned for seamless operations, which will be performed in the next reporting period.

TASKS TO BE PERFORMED IN THE NEXT PERIOD

1. Analyze the single vehicle test cases with adaptive grid method.
2. Continue formulation and implementation of the overset dynamic Chimera grid model.

CONTRACT PERFORMANCE AND FUNDING

58.33% of the proposed technical effort has been accomplished with 58.33% of the funding billed. No technical problem of the current model development has been encountered.
Stage separation process is an important phenomenon in multi-stage launch vehicle operation. The transient flowfield coupled with the multi-body systems is a challenging problem in design analysis. The thermodynamics environment with burning propellants during the upper-stage engine start in the separation processes adds to the complexity of the entire system. Understanding the underlying flow physics and vehicle dynamics during stage separation is required in designing a multi-stage launch vehicle with good flight performance. A computational fluid dynamics model with the capability to coupling transient multi-body dynamics systems will be a useful tool for simulating the effects of transient flowfield, plume/jet heating and vehicle dynamics. A computational model using generalise mesh system will be used as the basis of this development. The multi-body dynamics system will be solved, by integrating a system of six-degree-of-freedom equations of motion with high accuracy. Multi-body mesh system and their interactions are modeled using parallel computing algorithms. Dynamic stage separation CFD model will be developed with multiple-body detaching mechanism, body contact detection method and plume impingement heating effects modeled.