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# A General Multiblock Euler Code for Propulsion Integration,

## Volume III: User Guide for the Euler Code

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# 1. Table of Contents

# 1.0 Summary

This manual explains the procedures for using the general multiblock Euler (GMBE) code developed under NASA contract NAS1-18703. The code was developed for the aerodynamic analysis of geometrically complex configurations in either, free air or, wind tunnel environments (Vol. I). The complete flow field is divided into a number of topologically simple blocks, within each of which, surface-fitted grids and efficient flow solution algorithms can easily be constructed. The multiblock field grid is generated with the BCON procedure described in Volume II. GMBE utilizes a finite-volume formulation with an explicit time-stepping scheme to solve the Euler equations. A multiblock version of the multigrid method was developed to accelerate the convergence of the calculations. This user guide provides information on the GMBE code, including input data preparations with sample input files and a sample Unix script for program execution in the UNICOS environment.

## 2.0 Introduction

This overview focuses on the use of the GMBE code (Vol. I, Ref. 1) for the effective CFD simulation of complex problems. The simulation must begin with a good quality configuration geometry definition. This information is best provided by configuration aerodynamic engineers and designers who are familiar with the CFD code. Geometry corrections should be included to reflect the model aeroelasticity effects whenever possible.

Next, BCON (Vol. II, Ref. 2) is used to prepare the geometry data and job deck inputs to run the EAGLE code (Ref. 3) for volume grid generation. BCON will also generate the block-to-block relation and block-boundary condition files for the Euler solver. In addition, BCON can be useful for data checking to ensure that all information is correct, before it is passed to the flow solver.

The block-to-block relation file establishes the flow field communication between adjacent blocks. The block-boundary condition file provides information on the type of boundary condition to be applied on each block-face of each block. These three files together with a flow analysis input file are used for the general multiblock Euler analysis on the multiblock volume grid. The flow analysis input file specifies flow conditions and other controlling parameters.

This volume is the user guide for the GMBE code execution. Input data preparations with sample input files are presented in the next section. Guidelines for job deck preparations using UNICOS script files are given in Section 4.0. The script files are specific to the Cray Y-MP (reynolds) at the Numerical Aerodynamic Simulation (NAS) facility. However, the FORTRAN source of the GMBE code is portable on other Cray computers that have a large central memory (e. g., Cray-2). A grid for most practical applications typically has a large number of grid points, hence the data set from the Euler analysis is also very large. Post-processing programs, such as PLOT3D (Refs. 4, 5), are very useful for the graphical display of pertinent information extracted from the large flow field data set generated by GMBE. The data structure for the file containing the flow field solution is discussed in Section 5.0. File management is discussed in Section 6.0.

## 3.0 Input File Description

The flow analysis input file called "gmbein", described in the following sub-section, is required for GMBE execution. Another input file called "cutin", described in sub-section 3.2, is optional. The latter allows users to save output for pre-specified grid planes in pre-specified blocks. This can be very helpful if the user has a good idea of which region of the flow field he wishes to examine.

### 3.1 Preparation of the Flow Analysis Input File gmbein

This file is required by the multiblock Euler flow analysis program and contains information regarding the flow condition and other controlling parameters. Two sample input files are presented at the end of this subsection for easy references. Sample file one "gmbein-1" is prepared for a wing-mounted nacelle/propeller configuration. Sample file two "gmbein-2" is for an airplane with typical turbofan engines

| **Column** | **Code** | **Format** | **Description** |
|---|---|---|---|
| Card 1: | | | |
| 1-80 | TITLE | 10A8 | Title to describe the run output data. The title should include sufficient information for the user to identify his run at a later time (e.g., the configuration identification, the flight conditions, $M_\infty$, $\alpha$, etc.). |
| Card 2: | | | |
| 1-80 | | 1x | Header card. Header cards are essentially dummy cards provided for identification of the data in the following cards. Typically the |

| | | | |
|---|---|---|---|
| | | | fields in the header cards should include the generic names of the variables to be included in the field in the following card (s). The header cards are read in with format (1x), which means that they may contain any legal characters including blanks. |

Card 3:

| | | | |
|---|---|---|---|
| 1-10 | FCYC | F10.0 | Number of multigrid cycles.<br>Typical value = 500.0 |
| 11-20 | FPRNT | F10.0 | Number of multigrid cycles per one print out.<br>Recommended value = any number ≥ FCYC. |
| 21-30 | FTIM | F10.0 | Number of multigrid cycles per time step calculation.<br>Recommended value = 1.0 |
| 31-40 | GMESH | F10.0 | Multigrid levels for each block.<br>Recommended value = 2.0 |
| 41-50 | FIDMRY | F10.0 | Option to use either central memory or secondary storage devices such as disk or SSD to store the block data containing flow field and geometry information for each block.<br>= 0.0 use disk or SSD for storage.<br>= 1.0 use central memory for storage.<br>Recommended value = 1.0 |

Card 4:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 5:

| | | | |
|---|---|---|---|
| 1-10 | CFLF | F10.0 | CFL number for the fine (original) mesh. Negative CFL implies the use of local time-stepping. Positive value implies global time-stepping.<br>Recommended value = -6.0 |
| 11-20 | VIS0 | F10.0 | Dissipation coefficient for coarse grid.<br>VIS0 = 1.0 is equivalent to $K^{(0)} = 1/128$ in Equation (B10) in Appendix B in Volume I.<br>Recommended value = 1.0 |
| 21-30 | QFIL | F10.0 | Filter evaluation flag<br>= 1.0 evaluate two times for every time step if SN53 = 0.0 in column 61-70 in this card. evaluate three times for every time step if SN53 = 1.0 in this card.<br>= 0.0 evaluate once for every time step.<br>Recommended value = 1.0 |
| 31-40 | VIS2 | F10.0 | Coefficient for second order dissipation.<br>VIS2 = 1.0 is equivalent to $K^{(2)} = 1/4$ in Equation (B6) in Appendix B in Volume I.<br>Recommended value = 4.0 which means $K^{(2)} = 1$. |
| 41-50 | VIS4 | F10.0 | Coefficient for fourth order dissipation.<br>VIS4 = 1.0 is equivalent to $K^{(4)} = 1/128$ in Equation (B8) in Appendix B in Volume I.<br>Recommended value = 2.0 which means $K^{(4)} = 1/64$. |

| | | | |
|---|---|---|---|
| 51-60 | HMF | F10.0 | Coefficient for enthalpy damping for the fine mesh.<br>Recommended value = 0.2 if total energy level is uniform.<br>Recommended value = 0.0 for flow field with different total energy levels. |
| 61-70 | SN53 | F10.0 | Option to evaluate dissipation terms different number of times in Runge-Kutta integration.<br>= 0.0 use 5-2 scheme, five-stage Runge-Kutta with two evaluations of dissipation terms.<br>= 1.0 use 5-3 scheme, five-stage Runge-Kutta with three evaluations of dissipation terms.<br>Recommended value = 1.0<br>Some minor code changes are required to activate the six-stage Runge-Kutta option. |
| 71-80 | SNSFIL | F10.0 | Option to use different sensor terms in the 2nd order dissipation.<br>= 0.0 use pressure sensor.<br>= 1.0 use entropy sensor.<br>Recommended value = 0.0 for transonic flow calculation.<br>Recommended value = 1.0 for low speed flow calculation. |

Card 6:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 7:

C1 to C6 in this card are coefficients for multistage Runge-Kutta integration steps. The following values for five stage scheme are recommended.

| | | | |
|---|---|---|---|
| 1-10 | C1 | F10.0 | = 0.25 |
| 11-20 | C2 | F10.0 | = 0.166667 |
| 21-30 | C3 | F10.0 | = 0.375 |
| 31-40 | C4 | F10.0 | = 0.5 |
| 41-50 | C5 | F10.0 | = 1.0 |
| 51-60 | C6 | F10.0 | = 0.0 |

Card 8:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 9:

| | | | |
|---|---|---|---|
| 1-10 | SMOPI | F10.0 | Implicit smoothing parameter in the I-direction.<br>Recommended value = 2.0 |
| 11-20 | SMOPJ | F10.0 | Implicit smoothing parameter in the J-direction.<br>Recommended value = 2.0 |
| 21-30 | SMOPK | F10.0 | Implicit smoothing parameter in the K-direction.<br>Recommended value = 2.0 |
| 31-40 | START | F10.0 | Euler solution start option.<br>= 0.0 start from scratch. |

|  |  |  |  |
|---|---|---|---|
|  |  |  | = 1.0 continuation run. |

Card 10:

|  |  |  |  |
|---|---|---|---|
| 1-80 |  | 1x | Header card |

Card 11:

|  |  |  |  |
|---|---|---|---|
| 1-10 | FIBCN | F10.0 | Solid surface boundary condition whenever a patch of a constant-I block-face is a solid surface.<br>= 1.0 use normal momentum relation to compute the solid surface pressure.<br>= 0.0 use cell center value to approximate the solid surface pressure.<br>Recommended value = 0.0 for non-smooth grid. |
| 11-20 | FJBCN | F10.0 | Solid surface boundary condition whenever a patch of a constant-J block-face is a solid surface.<br>= 1.0 use normal momentum relation to compute the solid surface pressure.<br>= 0.0 use cell center value to approximate the solid surface pressure.<br>Recommended value = 0.0 for non-smooth grid. |
| 21-30 | FKBCN | F10.0 | Solid surface boundary condition whenever a patch of a constant-K block-face is a solid surface.<br>= 1.0 use normal momentum relation to compute the solid surface pressure.<br>= 0.0 use cell center value to approximate the solid surface pressure. |

| | | | |
|---|---|---|---|
| | | | Recommended value = 0.0 for non-smooth grid. |
| 31-40 | FICEN | F10.0 | Method of differencing along a JK block-face on solid surface for the pressure and the three components of the momentum.<br>= 1.0 central difference everywhere along both directions.<br>= 0.0 central difference everywhere along both directions but one-sided differences in I-direction normal to an edge of the block-face.<br>Recommended value = 1.0 |
| 41-50 | FJCEN | F10.0 | Method of differencing along an IK block-face on solid surface for the pressure and the three components of the momentum.<br>= 1.0 central difference everywhere along both directions.<br>= 0.0 central difference everywhere along both directions but one-sided differences in J-direction normal to an edge of the block-face.<br>Recommended value = 1.0 |
| 51-60 | FKCEN | F10.0 | Method of differencing along an IJ block-face on solid surface for the pressure and the three components of the momentum.<br>= 1.0 central difference everywhere along both directions.<br>= 0.0 central difference everywhere along both directions but one-sided differences in K-direction normal to an edge of the block-face. |

Recommended value = 1.0

Card 12:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 13:

| | | | |
|---|---|---|---|
| 1-10 | FITDO | F10.0 | Number of Euler integrations in each grid level in a V-cycle multigrid from the finest grid to the coarsest grid.<br>Recommended value = 1.0 |
| 11-20 | FITUP | F10.0 | Number of Euler integrations in each grid level in a V-cycle multigrid from the coarsest grid to the finest grid.<br>Recommended value = 0.0. This means interpolation only. |
| 21-30 | CFLC | F10.0 | CFL number for the coarse grid. Negative value implies the use of local time-stepping. Positive number implies global time-stepping.<br>Recommended value = -6.0 |
| 31-40 | HMC | F10.0 | Enthalpy damping coefficient for the coarse grid.<br>Recommended value = 0.0 |

Card 14:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 15:

| | | | |
|---|---|---|---|
| 1-10 | FMACH | F10.0 | Freestream Mach number. |
| 11-20 | ALPHA | F10.0 | Angle of attack (degrees). |
| 21-30 | ALYAW | F10.0 | Angle of yaw (degrees). |
| 31-40 | FIRUN | F10.0 | Option to initialize the Euler calculation with a computed solution obtained at a different freestream condition.<br>= 0.0 start from scratch or restart from a run with the same freestream condition.<br>= 1.0 start from a run with a different freestream condition. |
| 41-50 | RMOLD | F10.0 | Freestream Mach number for previous run. |
| 51-60 | ALOLD | F10.0 | Angle of attack (degrees) for previous run. |
| 61-70 | AYOLD | F10.0 | Angle of yaw (degrees) for previous run. |
| 71-80 | CD0 | F10.0 | Estimation of the viscous drag coefficient.<br>Default value = 0.0 |

Card 16:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 17:

This card defines the reference length and reference area in the Euler calculations. The units should be consistent with the geometry data for the configuration. For example, if the geometry data is given in inches, then the reference length will be in inches, and the reference area will be in square inches.

| | | | |
|---|---|---|---|
| 1-10 | AREF | F10.0 | Wing reference area. |

| | | | |
|---|---|---|---|
| 11-20 | XREF | F10.0 | Longitudinal location of the moment reference point. |
| 21-30 | YREF | F10.0 | Spanwise location of the moment reference point. |
| 31-40 | ZREF | F10.0 | Vertical location of the moment reference point. |
| 41-50 | CREF | F10.0 | Pitching moment reference length. |
| 51-60 | SREF | F10.0 | Yawing and rolling moments' reference length. |

Card 18:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 19:

| | | | |
|---|---|---|---|
| 1-10 | FMIN | F10.0 | Option flag for the fan inlet face boundary condition.<br>= 1.0 normal velocity boundary condition at fan inlet face (3(b) in Appendix C, Vol. I).<br>= 2.0 pressure boundary condition at fan inlet face (3(c) in Appendix C, Vol. I).<br>= 3.0 mass flux boundary condition at fan inlet face (3(a) in Appendix C, Vol. I). |
| 11-20 | QIN | F10.0 | Normal flow speed at the fan inlet face normalized by the freestream flow speed (FMIN=1.0), or<br>pressure at the fan inlet face normalized by the freestream flow speed (FMIN=2.0), or<br>mass flux at the fan inlet face normalized by the freestream flow speed (FMIN=3.0). |

| | | | |
|---|---|---|---|
| 21-30 | FEXT | F10.0 | Total number of different exhaust boundary conditions. FEXT is limited to two. Card 20 and 21 must not be present if FEXT is less than one. When FEXT equals one or two, then Card 20 and 21 are required input and number of data sets in Card 21 equals FEXT. |

Card 20:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 21:

| | | | |
|---|---|---|---|
| 1-10 | FMOUT | F10.0 | Option flag for fan exhaust boundary condition for each set.<br>= 1.0 freestream exhaust<br>= 2.0 freestream total temperature with a specified total pressure PSTG0<br>= 3.0 specify both total temperature TSTG0 and total pressure PSTG0 |
| 11-20 | PSTG0 | F10.0 | Total pressure (normalized by freestream static pressure) at the nacelle exhaust plane. Value used only if FMOUT = 2.0 or 3.0 |
| 21-30 | TSTG0 | F10.0 | Total temperature (normalized by freestream static temperature) at the nacelle exhaust plane. Value used only if FMOUT = 3.0 |
| 31-40<br>41-50<br>51-60 | FBEHT1<br>FBEHT2<br>FBEHT3 | F10.0 | Block number for the blocks that contain the nacelle exhaust plane. |

Card 22:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 23:

| | | | |
|---|---|---|---|
| 1-10 | FMDSK | F10.0 | Propeller disk option.<br>= 0.0 propeller disk-off<br>= 1.0 propeller disk-on (4(a) in Appendix C, Vol. I)<br>= 2.0 propeller disk-on (4(b) in Appendix C, Vol. I) |
| 11-20 | FIRDSK | F10.0 | Number of radial points at which propeller loading is described for each *theta* station. This number should equal to the number of numerical data cards in each data set in Card 29. |
| 21-30 | FITDSK | F10.0 | Number of *theta* stations at which propeller loading is described. This number should be no less than three and should be equal to the number of data sets in Card 27. |

Card 24:

| | | | |
|---|---|---|---|
| 1-80 | | 1x | Header card |

Card 25:

| | | | |
|---|---|---|---|
| 1-10 | XDSK0 | F10.0 | The x-coordinate of the propeller disk's center. |

|  |  |  |  |
|---|---|---|---|
| 11-20 | YDSK0 | F10.0 | The y-coordinate of the propeller disk's center. |
| 21-30 | ZDSK0 | F10.0 | The z-coordinate of the propeller disk's center. |
| 31-40 | RDSK | F10.0 | The radius of the disk. |
| Card 26: |  |  |  |
| 1-80 |  | 1x | Header card |
| Card 27: |  |  |  |
| 1-10 | TDS | F10.0 | *Theta* station in degrees measured counter-clockwise (looking aft) from a horizontal axis originating from the center of the propeller disk and pointing to the right. |
| Card 28: |  |  |  |
| 1-80 |  | 1x | Header card |
| Card 29: |  |  |  |
| 1-10 | RDS | F10.0 | Dimensional radial distance, measured from propeller disk center, at which loading is defined. |
| 11-20 | PSTG1 | F10.0 | Total pressure input (normalized by the freestream static pressure) immediate downstream of propeller disk (FMDSK=1.0), or thrust coefficient of the propeller disk (FMDSK=2.0). |
| 21-30 | TSTG1 | F10.0 | Total temperature input (normalized by the |

| | | | |
|---|---|---|---|
| | | | freestream static temperature) immediate downstream of propeller disk (FMDSK=1.0), or normal force coefficient of the propeller disk (FMDSK=2.0). |
| 31-40 | ALP1 | F10.0 | Swirl input in degree immediate downstream of propeller disk, looking aft, clockwise swirl is positive (FMDSK=1.0), or side force coefficient of the propeller disk (FMDSK=2.0). |

# Sample Flow Analysis Input File gmbein-1

```
GMBE Analysis for Wing/Nacelle/Propeller in Wind Tunnel/Disk On
FCYC      FPRNT     FTIM      GMESH     FIDMRY
 300.0     2000.     1.0       2.0       1.0
CFLF      VIS0      QFIL      VIS2      VIS4      HMF       SN53      SNSFIL
 -6.0      1.0       1.0       4.00      2.0       0.20      1.0       0.0
C1        C2        C3        C4        C5        C6
 0.2500    0.166667  0.375     0.5000    1.0000    0.0000
SMOPI     SMOPJ     SMOPK     START
 2.00      2.00      2.00       0.0
FIBCN     FJBCN     FKBCN     FICEND    FJCEND    FKCEND
  1.0       1.0       1.0      1.0       1.0       1.0
FITDO     FITUP     CFLC      HMC
 1.0       0.0       -6.0      0.0
FMACH     ALPHA     ALYAW     FIRUN     RMOLD     ALOLD     ALYOLD   CD0
 0.167     0.00      0.0       0.0       0.167     0.0000    0.0       0.0
AREF      XREF      YREF      ZREF      CREF      SREF
 4000.000  135.0       0.0       0.0     100.0     400.0
FMIN      QIN       FEXT
 1.0       0.60      0.0
FMDSK     FIRDSK    FITDSK
 1.0       20.0      13.0
XDSK0     YDSK0     ZDSK0     RDSK
 32.68667  0.0       0.0       72.0
TDS
 -180.0
RDS       PSTG1     TSTG1     ALP1      THETA=-180.000000
12.427     1.019030  1.005578  2.530
13.680     1.019631  1.005578  2.807
15.840     1.020604  1.005578  3.300
18.000     1.021410  1.005578  3.831
21.600     1.022216  1.005578  4.700
25.200     1.022529  1.005578  5.172
28.800     1.022743  1.005578  5.200
32.400     1.022902  1.005578  5.029
36.000     1.023017  1.005578  4.800
39.600     1.023122  1.005578  4.546
43.200     1.023193  1.005578  4.300
46.800     1.023212  1.005578  4.051
```

```
50.400      1.023193  1.005578  3.700
54.000      1.023161  1.005578  3.095
57.600      1.023056  1.005578  2.500
61.200      1.022846  1.005578  2.271
64.800      1.022470  1.005578  2.000
68.400      1.021845  1.005578  1.200
70.560      1.020632  1.005578   .165
72.000      1.019347  1.005578  -.900
TDS
 -150.0
RDS        PSTG1     TSTG1     ALP1      THETA=-150.000000
12.427      1.019015  1.005578  3.310
13.680      1.019631  1.005578  3.537
15.840      1.020604  1.005578  3.943
18.000      1.021410  1.005578  4.380
21.600      1.022216  1.005578  5.095
25.200      1.022529  1.005578  5.476
28.800      1.022743  1.005578  5.468
32.400      1.022902  1.005578  5.276
36.000      1.023017  1.005578  5.034
39.600      1.023122  1.005578  4.771
43.200      1.023193  1.005578  4.514
46.800      1.023212  1.005578  4.252
50.400      1.023193  1.005578  3.888
54.000      1.023161  1.005578  3.269
57.600      1.023056  1.005578  2.661
61.200      1.022846  1.005578  2.421
64.800      1.022470  1.005578  2.141
68.400      1.021845  1.005578  1.334
70.560      1.020632  1.005578   .289
72.000      1.019347  1.005578  -.786
     .
     .
     .
TDS
  180.0
RDS        PSTG1     TSTG1     ALP1      THETA=180.000000
12.427      1.019015  1.005578  2.530
13.680      1.019631  1.005578  2.807
15.840      1.020604  1.005578  3.300
18.000      1.021410  1.005578  3.831
21.600      1.022216  1.005578  4.700
25.200      1.022529  1.005578  5.172
28.800      1.022743  1.005578  5.200
```

|  |  |  |  |
|---|---|---|---|
| 32.400 | 1.022902 | 1.005578 | 5.029 |
| 36.000 | 1.023017 | 1.005578 | 4.800 |
| 39.600 | 1.023122 | 1.005578 | 4.546 |
| 43.200 | 1.023193 | 1.005578 | 4.300 |
| 46.800 | 1.023212 | 1.005578 | 4.051 |
| 50.400 | 1.023193 | 1.005578 | 3.700 |
| 54.000 | 1.023161 | 1.005578 | 3.095 |
| 57.600 | 1.023056 | 1.005578 | 2.500 |
| 61.200 | 1.022846 | 1.005578 | 2.271 |
| 64.800 | 1.022470 | 1.005578 | 2.000 |
| 68.400 | 1.021845 | 1.005578 | 1.200 |
| 70.560 | 1.020632 | 1.005578 | .165 |
| 72.000 | 1.019347 | 1.005578 | -.900 |

# Sample Flow Analysis Input File gmbein-2

```
GMBE Analysis for NASA Wing/Body Underwing Nacelle/Pylon
FCYC      FPRNT    FTIM      GMESH     FIDMRY
 250.0    2000.       1.0     2.0       1.0
CFLF      VISO      QFIL      VIS2      VIS4      HMF       SN53      SNSFIL
 -6.0      1.0       1.0       4.00      2.0       0.20      1.0       0.0
C1        C2        C3        C4        C5        C6
 0.2500    0.166667  0.375     0.5000    1.0000    0.0000
SMOPI     SMOPJ     SMOPK     START
 2.00      2.00      2.00      0.0
FIBCN     FJBCN     FKBCN     FICEND    FJCEND    FKCEND
  1.0       1.0       1.0      1.0       1.0       1.0
FITDO     FITUP     CFLC      HMC
 1.0       0.0       -6.0      0.0
FMACH     ALPHA     ALYAW     FIRUN     RMOLD     ALOLD     ALYOLD    CD0
 0.77      0.500     0.0       0.0       0.7700    0.500     0.0       0.0
AREF      XREF      YREF      ZREF      CREF      SREF
294.000    41.9        0.0       0.0     8.176     80.0
FMIN      QIN       FEXT
 1.0       0.60      2.0
FMOUT     PSTG0     TSTG0     FBEHT1     FBEHT2    FBEHT3
 1.0       1.4802    1.1186    4.0        5.0       6.0
 1.0       1.4802    1.1186    7.0        8.0       9.0
FMDSK     FIRDSK    FITDSK
 0.0
```

## 3.2 Preparation of the Input File cutin

This input file is prepared for saving output at a pre-specified cutting plane. The cutting plane data is prepared in a block-by-block manner. Within a block, a cutting plane can be on a constant-I, constant-J, or constant-K grid plane where the I, J, and K are the local indexing coordinates. The I, J, and K are used to number the grid planes in the corresponding directions starting from two (corresponding to a block-face) up to the last grid plane on another block-face. Grid plane one is reserved for the extra grid layer for interchange geometry information with neighboring blocks. A cutting plane can be either on a block-face or in the interior of a block. A sample input file is listed at the end of this subsection.

| **Column** | **Code** | **Format** | **Explanation** |
|---|---|---|---|
| Card 1: | | | |
| 1-80 | | 1X | Header card |
| Card 2: | | | |
| 1-10 | FNN | F10.0 | Block number |
| 11-20 | FIDUM | F10.0 | Number of constant-I cutting planes, up to eight planes within a block. Skip cards 3 & 4 if FIDUM = 0.0. |
| 21-30 | FJDUM | F10.0 | Number of constant-J cutting planes, up to eight planes within a block. Skip cards 5 & 6 if FJDUM = 0.0. |
| 31-40 | FKDUM | F10.0 | Number of constant-K cutting planes, up to eight planes within a block. |

Skip cards 7 & 8 if FKDUM = 0.0.

Card 3:

| | | | |
|---|---|---|---|
| 1-80 | | 1X | Header card |

Card 4:

| | | | |
|---|---|---|---|
| 1-10 | FIDPLI1 | F10.0 | I index for first constant-I cutting plane,<br>The minimum I-index within a block is two. |
| 11-20 | FIDPLI2 | F10.0 | I index for 2nd constant-I cutting plane. |
| | . | | |
| | . | | |
| 71-80 | FIDPLI8 | F10.0 | I index for 8th constant-I cutting plane. |

Card 5:

| | | | |
|---|---|---|---|
| 1-80 | | 1X | Header card |

Card 6:

| | | | |
|---|---|---|---|
| 1-10 | FIDPLJ1 | F10.0 | J index for first constant-J cutting plane,<br>The minimum J-index within a block is two. |
| 11-20 | FIDPLJ2 | F10.0 | J index for 2nd constant-J cutting plane. |
| | . | | |
| | . | | |

|  |  |  |  |
|---|---|---|---|
| 71-80 | FIDPLJ8 | F10.0 | J index for 8th constant-J cutting plane. |
| Card 7: |  |  |  |
| 1-80 |  | 1X | Header card |
| Card 8: |  |  |  |
| 1-10 | FIDPLK1 | F10.0 | K index for first constant-K cutting plane, The minimum K-index within a block is two. |
| 11-20 | FIDPLK2 | F10.0 | K index for 2nd constant-K cutting plane. |
|  | . |  |  |
|  | . |  |  |
| 71-80 | FIDPLK8 | F10.0 | K index for 8th constant-K cutting plane. |

Repeat cards 1-8 for the next block from which to extract data.

# Sample Input File cutin

```
FNN       FIDUM     FJDUM     FKDUM
 3.0       3.0       0.0       3.0
FIDPLI1
 2.0       24.0      46.0
FIDPLK1
 2.0       22.0      42.0
FNN       FIDUM     FJDUM     FKDUM
 4.0       3.0       0.0       3.0
FIDPLI1
 2.0       24.0      46.0
FIDPLK1
 2.0       22.0      42.0
```

# 4.0 Program Execution

It is convenient to use Unix script files for GMBE execution. The script file "jobexlg" described in sub-section 4.1 converts the multiblock grid from EAGLE format to GMBE format. Once this is done, another script file "jobgmbe" discussed in sub-section 4.2 is used for the execution of GMBE code. Some comments on National Aerodynamic Simulation (NAS) operations are given in sub-section 4.3 from a NAS user's perspective. Checklists have also been developed and presented in sub-section 4.4 to ensure that the Unix script for a GMBE run has been prepared correctly.

## 4.1 Using Script File jobexlg

A sample Unix script file, "jobexlg" is presented at the end of this subsection. This script file converts the multiblock grid file from EAGLE format to GMBE format. The converted grid file is saved for subsequent GMBE execution. The EAGLE grid file, the block-to-block relation file and block boundary condition file are required input to run this script file. This script file can be submitted to the Network Queuing System (NQS), which provides a batch execution of the grid converter code on NAS CRAY Y-MP (reynolds) in the UNICOS environment. To submit the file to NQS, use the command line (following a typical prompt such as reynolds.me%):

```
reynolds.me% qsub jobexlg
```

This job requires less than 10 MW of central memory and less than 600 CPU seconds. Under the current NAS policy, such a job can also run interactively. To do so, use the simple command line:

```
reynolds.me% jobexlg
```

For running the same job interactively in the background mode, type:

```
reynolds.me% jobexlg &
```

## Sample Script File jobexlg

```
#@$-eo
#@$-o /scr8/hchen/wbnsm/jobexlg.log                # destination logfile
#@$-lM 8Mw                                         # memory requested
#@$-lT 300                                         # time limit for job
#
# This is a sample UNICOS script file to convert the multiblock grid
# from EAGLE format to GMBE format
# This script file, jobexlg, is stored in
# /scr8/hchen/wbnsm
# The grid converter will be compiled and executed on NAS CRAY Y-MP
#
# In this example
# FORTRAN source files are fetch from permanent file directory
# /scr8/hchen/soce
#
# Grid file with block-to-block relation and block boundary
# condition files are fetched from scratch file directory
# /scr8/hchen/in
#
# Files created during program execution are stored in
# scratch file directory
# /scr8/hchen/wbnsm/try2
# At the end of the program execution, temporary files in this
# directory will be deleted
#
cd ~/wbnsm/try2                                    # scratch file directory
#                                                  # for program execution
cp /u/re/hchen/soce/exparm.f .
#
echo "compile of /scr8/hchen/soce/exparm.f"
#
cf77 -o expmx exparm.f
#
# link the grid file to fort.1
#
ln /scr8/hchen/in/gf29 fort.1
```

```
#
echo "execution of expmx"
#
# Executing the pre-processing code using the flow analysis
# input file
#
expmx > expout
#
echo "create nplex from source for update /u/re/hchen/soce/exlayer"
#
update -i /u/re/hchen/soce/exlayer -n nplex -f
update -p nplex -i fort.7 -c exlay -f
#
cf77 -o exlax exlay.f
#
# link the block-to-block relation file to fort.3
#
ln /scr8/hchen/in/bco.c2 fort.2
ln /scr8/hchen/in/relo.dat fort.3
echo "execution of exlayer"
#
# Executing the pre-processing code using the flow analysis
# input file
#
exlax > exlout
mv fort.4 /scr8/hchen/in/gf29hc
/bin/rm *
```

## 4.2 Using the Script File jobgmbe

A sample Unix script file, "jobgmbe" is presented at the end of this subsection. This script file is used to execute the GMBE code on the NAS Cray Y-MP (reynolds) in the UNICOS environment. To submit the file to NQS, use the command line:

```
reynolds.me% qsub jobgmbe
```

NQS provides computing services for several different job queues based on the machine resources requested for each job (Ref. 6). If a job requires less machine resources it would generally have a better turn around time. It is, therefore, beneficial to have a good estimation of machine resource utilization. A typical test case using one million grid points would use up to 16 MW of central memory. Approximately three and half hours of (single) CPU time are required to run the 500 multigrid steps typically required for a converged run. Currently, NQS limits CPU time to four hours (14,400 seconds). The sample script file (pg. 31) requested 7,200 seconds of CPU time which is adequate for 250 multigrid steps (pg. 20). Notice that deferred priority is specified. This limits the CPU time to no more than 7,200 seconds under the current NQS policy.

If the script file "jobgmbe" is properly modified for a smaller test case requiring no more than 10 MW of central memory, the user can conduct a quick check-out run (no more than 600 CPU seconds) interactively (pg. 25).

For a general flow field simulation, it would be very useful to adjust the memory requirement to each grid in the GMBE analysis. To make this process user-friendly, a pre-processor (sprm.f on pg. 31) of the GMBE code is used for managing the central memory requirement in the Euler calculations. Grid information is read in by this pre-processor code. It creates a file (fort.7 on pg. 32) updating the GMBE program library to allocate the right amount of memory for Euler calculations. The procedure to run this pre-processor is integrated into the sample script file. As shown in this script file, the flow analysis input file "gmbein", discussed in Section 3.1, is a required input for this pre-processor. In addition, the multiblock grid file in GMBE format (fort.1 on pg. 32) and the block-to-block relation file (fort.3 on pg. 32) are also required input. All these three files are subsequently used as input to GMBE execution as well.

The permanent file disk space is generally very limited for a typical NAS account while the scratch file disk space is usually adequate for a run. This sample script file shows that only the program source files are fetched from the permanent file disk. All other files, including input data and output from GMBE analysis are fetched from, or stored on, the scratch file disk. Details are given in the script file. In addition to the three input files mentioned previously, the block boundary condition file is also required (fort. 2 on pg. 32) for GMBE execution.

There are two ways to run the GMBE code. One is to start the solution from scratch (a start-up run). The other is to do a continuation run or restart from a previous solution. The sample script file is prepared for a start-up run. To modify this script file for a restart run, two things need to be done. Firstly, the variable START in Card 9 of the flow analysis input file "gmbein" should be set to 1.0 indicating that the restart option has been selected. Secondly, in the script, before executing GMBE, the command line to move the flow field solution file for restart to fort.10 should be activated.

At the end of Euler analysis, fort.10 will be over-written by a new flow field solution. Using the same I/O unit for both input and output of the restart file implies that only one copy of the restart file is written on the scratch disk space. This allows for a much better disk space utilization. More discussion on this flow field solution file is given in the next section on output analysis.

A typical one million grid point case requires approximately 20,000 blocks (each block contains 4,096 64-bit words) of (scratch) disk space to run. Approximately 2/3 of the disk space is used by the restart file and 1/3 by the multiblock grid file.

GMBE also allows an user to have an option to save analysis output on pre-specified cutting planes in a block-by-block manner. To activate this option, the user must prepare an input file "cutin" as described in sub-section 3.2. This file (fort.4 on pg. 33) will be read in by GMBE code. The corresponding output file will be written on fort.51. The command lines to use this option have been commented out on page 33.

# Sample Script File jobgmbe

```
#@$-eo
#@$-o /scr8/hchen/wbnsm/jobgmbe.log             # destination logfile
#@$-lM 16Mw                                     # memory requested
#@$-lT 7200                                     # time limit for job
#@$-q defer                                     # use defer queue
#
# This is a sample UNICOS script file to compile and execute the
# GMBE code on NAS Cray Y-MP
#
# In this example
# FORTRAN source files are fetch from permanent file directory
# /u/re/hchen/soce
#
# The grid file, the block-to-block relation and the block boundary
# condition files are fetched from scratch file directory
# /scr8/hchen/in
#
# Flow analysis input file is fetched from scratch file directory
# /scr8/hchen/wbnsm
# this is also the directory where this script file be stored
#
# Files created during program execution are stored in
# scratch file directory
# /scr8/hchen/wbnsm/try
# At the end of the program execution, temporary files in this
# directory will be deleted
#
cd /scr8/hchen/wbnsm/try                        # scratch file directory
#                                               # for program execution
echo "compile of /u/re/hchen/soce/sprm.f"
#
# Compilation of a pre-processing code sprm.f
# Grid information are read in and processed by this code
# to specify the memory requirement for general multiblock
# Euler (GMBE) calculation
#
cf77 -o parex /u/re/hchen/soce/sprm.f
```

```
#
# Link the grid file to fort.1
#
ln /scr8/hchen/in/gf29hc fort.1
#
# Copy the block-to-block relation file to fort.3
#
cp /scr8/hchen/in/relo.dat fort.3
echo "execution of sprm"
#
# Executing the pre-processing code using the flow analysis
# input file
#
parex < /scr8/hchen/wbnsm/gmbein-2 > parout
#
# The pre-processing code creates an update file in fort.7
# which will be used to update the program library of the
# GMBE code
#
mv fort.7 mdbq01
echo "update from source for update"
#
# Create GMBE program library from source for update
#
update -i /u/re/hchen/soce/gmbe.re -n npl01 -f
echo "update using mod file"
#
# Update the GMBE program library using fort.7 (mdbq01)
# created by the pre-processing code for memory management
#
update -p npl01 -i mdbq01 -c gmbeu -f
echo "compile of gmbeu"
#
# compile the GMBE FORTRAN source file gmbeu.f
#
cf77 -o gmbex -ZL gmbeu.f
#
# copy the block boundary condition file to fort.2
#
cp /scr8/hchen/in/bco.c2 fort.2
```

```
#
# If cutting file option is selected link the cutin file
# to fort.4
#
# ln /scr8/hchen/wbnsm/cutin fort.4
#
# If this is a restart run then move the restart file to fort.10
#
# mv /scr8/hchen/wbnsm/fnbq01 fort.10
#
echo "execution of gmbex"
#
# Execution of GMBE code using the flow analysis input file
#
gmbex < /scr8/hchen/wbnsm/gmbein-2 > /scr8/hchen/wbnsm/obq01
echo "save files"
#
# Move some output files back
#
mv fort.3 /scr8/hchen/wbnsm/cvbq01
mv fort.50 /scr8/hchen/wbnsm/cpbq01
mv fort.10 /scr8/hchen/wbnsm/fnbq01
#
# If cutting file option is selected the results will be
# saved on fort.51 move it back to current directory
#
# mv fort.51 /scr8/hchen/wbnsm/ffbq01
#
# Remove temporary files
#
/bin/rm fort* gmbe* npl01 parex parout
# End of job
```

## 4.3 Notes on NAS Usage

The NAS facility was established to support computationally intensive research projects requiring substantial amounts of supercomputer time especially those projects of national significance for future technology applications. Under such guidelines, NAS provide valuable computational resources to a large number of users in government, industry and universities. NAS has been continuously acquiring the most powerful supercomputers in this nation as soon as they became available. Serving a large nationwide user base in such an expanding environment requires NAS to update their policy periodically. It is therefore important for a NAS user to be aware of the basic (Ref. 6) and the up-to-date NAS policy.

Pertinent to runing batch jobs on reynolds through NQS, a user should review the most current policy on NQS limits. NQS divides the batch jobs into seven queue-groups. These are: the debug queue-groups; five queue-groups using non-deferred priority but with different memory requirements; and the deferred queue-group. Generally, each queue-group is further divided into several queues based on CPU time and/or memory requirements. The current NQS policy limits a user to have no more than one executing job in each of the queue-groups. The limitation is more restrictive for deferred jobs; there can be only one queued job in the deferred queue-group. For example, two deferred jobs queued in the deferred queue-group constitutes a violation even if none of the jobs have been executed. Adhering to such queuing-policies is important. Any violation may result in NQS deleting the jobs without notice.

The deferred queue provides a mechanism that allows computing with no charge against project allocation during idle times. System parameters are checked periodically to determine whether to start a new job. If memory and CPU time are available, then new non-deferred jobs will start. During the week, the supercomputers at NAS are nearly fully subscribed. Deferred jobs are more likely to be executed over the weekend. It is necessary to make sure that input files for the job remain online at the time of execution. As a mean of disk space management, NAS automatically cleans up a user's files on a scratch disk if those files have not been accessed for three days. Please refer to Section 6.0 for further information on file management.

Proper utilization of the deferred queue can be very helpful to a NAS project. It may become the only alternative when the project allocation is essentially exhausted.

## 4.4 Checklists for a NQS Job

Before submitting a script to NQS on reynolds at NAS for GMBE execution, it is useful to go through the following checklists to ensure that the job will be run properly. The checklists are designed especially for the NASA low wing transport (Vol. I, pg. 10) test case using a multiblock grid of over 1,000,000 grid points. For a different case, the disk space requirement discussed in item three will be different and should be modified accordingly.

1. Make sure the job will be run in the right queue. For example, the command line for requesting the deferred queue must be in the script if it is the user's intention to do so.

2. Make sure that the CPU time and central memory requested is appropriate for the run. Insufficient allocation will cause the run to abort.

3. Make sure there is sufficient scratch disk space available in the user's NAS account. Assuming that the multiblock grid has already been stored in the disk, a start-up run will require approximately 15,000 more blocks of disk space to allow for storage of the flow field solution file (also called restart file, sub-section 5.1). A continuation run with the restart file already on the disk will require approximately 1,000 more blocks.

4. Make sure that the script uses the correct block boundary-condition file. Failure to do so will require a rerun.

5. A GMBE run will generate a number of output files. These output files must be removed before a user executes the same GMBE job that will create more output files under the same names. Existence of any previously named output files will

cause the run to abort if the user has specified a "noclobber" shell environment.

6. Make sure that all input files for the GMBE program executions are available and accessible.

7. The restart file should be saved on MSS before being used for a continuation run, as it will be over-written by the updated Euler solutions.

## 5.0 Output Analysis

A successive flow analysis will generate several useful output files. The primary output is a flow field solution file that is stored in fort.10 in binary format. This file is described in the following sub-section. Two other useful files in ascii format are also stored. These are the surface pressure file and the convergence history file, stored in fort.50 and fort.3, respectively. Associated with each GMBE run there is also a log file containing diagnostic and timing/resource utilization information.

### 5.1 Flow Field Solution File

This flow solution file contains six flow variables, namely density ($\rho$), x-momentum ($\rho u$), y-momentum ($\rho v$), z-momentum ($\rho w$), total energy ($\rho E$) and pressure ($p$). The density and the pressure are normalized with respect to their freestream values. The total energy and the total enthalpy are normalized with respect to the ratio between the freestream pressure and freestream density $P_\infty/\rho_\infty$, and the velocity is normalized with respect to the square root of $P_\infty/\rho_\infty$. Notice that the normalized freestream flow speed is equal to $\gamma^{1/2}$ $M_\infty$ instead of one.

This flow solution file is also referred to as the restart file although restarting a continuation run from a previous analysis is not the primary reason for saving this file.

In this file, the six flow variables are stored in a block-by-block manner for every grid point for the entire flow field. The file is therefore very big when the problems are complex and involve a large number of grid points. In order to read in this file for extraction or reduction of the contained data, the multiblock grid file must first be read in to provide the data structure information. The following coding section illustrates how this can be done. In this example, fort.1 is the multiblock grid file and fort.10 is the restart file.

The grid dimensions of each block include an extra grid plane beyond each of the six block-faces. The cell dimensions storing the Euler solution vectors include two extra cell layers beyond each of the six block-faces.

The post-processing computations can be implemented within DO LOOP 40 with the processed results stored for use by graphics code such as the PLOT3D (Ref. 4) program. The user ensure that the reference quantities for the normalization of flow variables are identical between the GMBE and the graphics code. The grid coordinates are stored in the cell corners but the Euler solution vectors are stored in the cell centers. The solution vectors must be averaged to the cell corners.

# Coding Section for Inputing Restart File

```
C
C     I/O Unit number (fort.1) for multiblock grid file
C
      INGRD =  1
C
C     I/O Unit number (fort.10) for restart file
C
      INQ   = 10
C
C     Read NB for total number of blocks
C
      READ (INGRD) NB
      DO 20 IB = 1,NB
C
C        Read grid dimension for block IB
C        NI(IB) in the i-direction
C        NJ(IB) in the j-direction
C        NK(IB) in the k-direction
C
         READ (INGRD) NI(IB),NJ(IB),NK(IB)
C
C        Do loop 10 skips the grid coordinates input for a block
C
         DO 10 K = 1,NK(IB)
C
C     correct form to read in grid coordinates are:
C
C     READ (INGRD) (X(I,J,K),I=1,NI(IB)),J=1,NJ(IB))
C     READ (INGRD) (Y(I,J,K),I=1,NI(IB)),J=1,NJ(IB))
C     READ (INGRD) (Z(I,J,K),I=1,NI(IB)),J=1,NJ(IB))
C
```

```
               READ (INGRD)
               READ (INGRD)
               READ (INGRD)
   10          CONTINUE
   20       CONTINUE
C
C        Restart file dimensions are one greater than grid file
C
         DO 30 IB = 1,NB
            NI(IB) = NI(IB) + 1
            NJ(IB) = NJ(IB) + 1
            NK(IB) = NK(IB) + 1
   30       CONTINUE
C
C        Do loop 40 read in flow field solution block-by-block
C        Please code in coding for post-processing right after
C        the READ statement
C
         DO 40 IB = 1,NB
            READ (INQ) (W(M,I,J,K),M=1,6),I=1,NI(IB),J=1,NJ(IB),
     1                 K=1,NK(IB))

              .

              .

            Coding for post-processing

              .

              .

   40       CONTINUE
C
C        Input flow condition in the next executable statement
C
```

```
C      Title should have the dimension of TITLE(10)
C      it stores the title information for an Euler analysis
C      RM is the freestream Mach number
C      AL is the angle of attack
C      NRES is the iteration count
C      M = 1
C
       READ (INQ) NRES,M,TITLE,RM,AL
```

## 5.2 Surface Pressure File

The surface pressure file contains grid points on the configuration surface, together with the corresponding pressure coefficient and Mach number distributions. For a configuration with a powered nacelle, this file also includes the fan inlet face and engine exhaust face. For a propeller at power on condition, the results include both sides of the propeller plane. The data is stored in network format.

## 5.3 Convergence History File

This file records statistics on each time step as the computation proceeds toward convergence to the steady state solution. Explanation for the variables listed in this file is given below:

| **Code** | **Description** |
|---|---|
| NCYC | Time-stepping iteration count |
| NB1 | Block number in which maximum residual occurs |
| RTMAX | Maximum residual |
| IRT | I-index in the block for maximum residual |
| JRT | J-index in the block for maximum residual |
| KRT | K-index in the block for maximum residual |
| RTRMS | Average residual |
| NB2 | Block number in which maximum enthalpy occurs |
| HMAX | Maximum enthalpy |
| HRMS | Average enthalpy |
| NSUP | Total number of supersonic points for all blocks |

The variable RTMAX for maximum residual is the most critical for GMBE convergence. Approximately three order of magnitude reduction in RTMAX is sufficient for convergence.

# 6.0 File Management

This discussion is pertinent to the NAS operation. A user in a different supercomputer center may not need to clean up the online disk space as often if a large amount of online disk space is available. However, since the online disk space is usually very expensive, it is still a good practice to move large files to less expensive storage devices. Good file management allows more resources to be allocated for computation than for data storage.

The GMBE code can generate a large size data set for each analysis of a complex configuration. Since the available disk storage is limited, proper file management are essential. The majority of the data files should be transferred to local work-stations for CFD visualization whenever possible. The restart file, however, may also be needed as input to GMBE code for a continuation run. This file should be moved to "prandtl" machine (using rcp command) for possible future usage. In so doing, the (scratch) disk space can be released for conducting other analyses. The multiblock grid file should also be moved to prandtl if the file may not be accessed for three days or more. Refer to NAS User Guide (Ref. 6) for more detail.

## 7.0 References

1. Chen, H. C., Su T. Y., and Kao, T. J., "A General Multiblock Euler Code for Propulsion Integration, Volume I: Theory Document," NASA CR-187484, Volume I, May 1991.
2. Su, T. Y., Appleby, R. A., and Chen, H. C., "A General Multiblock Euler Code for Propulsion Integration, Volume II: User Guide for BCON, Pre-Processor for Grid Generation and GMBE, " NASA CR-187484, Volume II, May 1991.
3. Lijewski, E., and Cipolla, J., "Program EAGLE User's Manual," USAF Armament Laboratory Technical Report, AFATL-TR-88-117, Eglin AFB, September 1988.
4. Buning, P. G., and Steger, J. L., "Graphics and Flow Visualization in Computational Fluid Dynamics," AIAA Paper 85-1507, July 1985.
5. Walatka, P. P., Bunning, P. G., Pierce, L., Elson, P. A., "PLOT3D User's Manual," NASA TM-101067, March 1990.
6. NAS Systems Division, "NAS User Guide, Version 5.1," NASA Ames Research Center, October 1990.

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16. Abstract

This manual explains the procedures for using the general multiblock Euler (GMBE) code developed under NASA contract NAS1-18703. The code was developed for the aerodynamic analysis of geometrically complex configurations in either, free air or, wind tunnel environments (Vol. I). The complete flow field is divided into a number of topologically simple blocks, within each of which, surface-fitted grids and efficient flow solution algorithms can easily be constructed. The multiblock field grid is generated with the BCON procedure described in Volume II. GMBE utilizes a finite-volume formulation with an explicit time-stepping scheme to solve the Euler equations. A multiblock version of the multigrid method was developed to accelerate the convergence of the calculations. This user guide provides information on the GMBE code, including input data preparations with sample input files and a sample Unix script for program execution in the UNICOS environment.

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