AN UPGRADE OF THE AEROHEATING SOFTWARE “MINIVER”

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ABSTRACT

Many software packages assist engineers with performing flight vehicle analysis, but some of these packages have gone many years without updates or significant improvements to their workflows. One such software package, known as MINIVER, is a powerful yet lightweight tool used for aeroheating analyses. However, it is an aging program that has not seen major improvements within the past decade. As part of a collaborative effort with the Florida Institute of Technology, MINIVER has received a major user interface overhaul, a change in program language, and will be continually receiving updates to improve its capabilities.

The user interface update includes a migration from a command-line interface to that of a graphical user interface supported in the Windows operating system. The organizational structure of the pre-processor has been transformed to clearly defined categories to provide ease of data entry. Helpful tools have been incorporated, including the ability to copy sections of cases as well as a generalized importer which aids in bulk data entry. A visual trajectory editor has been included, as well as a CAD Editor which allows the user to input simplified geometries in order to generate MINIVER cases in bulk.

To demonstrate its continued effectiveness, a case involving the JAXA OREX flight vehicle will be included, providing comparisons to captured flight data as well as other computational solutions. The most recent upgrade effort incorporated the use of the CAD Editor, and current efforts are investigating methods to link MINIVER projects with SINDA/Fluint and Thermal Desktop.

NOMENCLATURE, ACRONYMS, ABBREVIATIONS

CAD	Computer-Aided Design
CFD	Computational Fluid Dynamics
KSC	Kennedy Space Center
LSP	Launch Services Program
OREX	Orbital Re-entry Experiment

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INTRODUCTION

Modern computing allows engineers to utilize Computational Fluid Dynamics (CFD) to calculate detailed and accurate information regarding the flow of a fluid over a body. This process, however, can take a significant effort to set up and execute. The computational domain, composed of a grid of nodes where calculations take place, can be fairly simple for basic shapes. This becomes increasingly complex for unusual 2D geometries and 3D geometries in general. In areas of great import, the grid must be made fine, which adds to computational time for the simulation. In general, while CFD is a very strong tool for fluid analysis, it suffers at certain steps of vehicle engineering where parametric design is paramount and time can be at a premium. Faster software must be used to provide reasonable estimates which can help set the stage for highly accurate CFD studies.

MINIVER is one such software tool. Using theoretical and empirical correlations, MINIVER can take a vehicle's trajectory and geometry, combined with an atmospheric model, and formulate fluid property calculations in the flowfield at the vehicle's surface. MINIVER then utilizes these properties along with a selected heat transfer methodology to calculate heat loads and fluxes at the surface. The user creates "cases" which represent body points on the vehicle, where setup time is on the order of minutes and run times on the order of seconds. This is in contrast to CFD models, which can take hours, days, or longer, depending on the model requirements and complexity.

While MINIVER adequately fills the role of providing fast, reasonably accurate analyses, it suffers from a rigid, command-line interface and lackluster documentation in an age where user-friendly, graphical interfaces and thorough documentation are the norms. To explore the possibility of creating a modern interface and opening the way for further improvements, the Launch Services Program at NASA Kennedy Space Center initiated a special study with the Florida Institute of Technology. The results of the first phase of development, summarized in this paper, include an updated interface, the addition of helpful tools, and the inclusion of a basic CAD geometry editor for use with creating bulk cases from imported geometry.

UPGRADE AND CONVERSION OF THE MINIVER SOFTWARE

The version of MINIVER used in this conversion process was based on the 1983 REMTECH upgrade by Engel, Praharaj, and Schmitz.[1,2] Additionally, comments within the source code indicate that additional upgrades were performed around 2000 and 2003. Using this code as a basis, the MINIVER modules known as PREMIN (the preprocessor) and LANMIN (the processor) were selected to be upgraded to a modern version. The third module, EXITS (TPS structural analyzer) was not carried over as it does not receive exceptional use as the other modules do.

PREMIN Conversion

Legacy PREMIN prompts the user for input via a command-line interface, an example of which is shown in Figure 1. In order, PREMIN requests:

1. Whether to use English or Metric units for data input
2. What time intervals to use for data printout
3. Vehicle trajectory; manual input or file import
4. Which atmosphere model to use
5. Which heat transfer model to use
6. How to consider flow transition
7. Whether to consider crossflow or not
8. What type of flowfield and pressure environment to consider
9. If the surface geometry changes over time
10. How the wall temperature should be determined
11. How the user wants the output file to be generated

```
 trajectory input is complete



     atmosphere data

 options     1.  1962 u.s. standard atmosphere
             2.  wind tunnel option
             3.  input atmospheric data(alt,t-inf,p-inf)
             4.  1963 patrick air force base atmosphere
             5.  1971 vandenberg reference atmosphere
             6.  1973 vandenberg hot day atmosphere
             7.  1973 vandenberg cold day atmosphere
             8.  1971 kennedy hot day atmosphere
             9.  1971 kennedy cold day atmosphere
            10.  1976 u.s. standard atmosphere

 option selected ?
10

 1976 u.s. standard atmosphere

 is this option correct ?
y



 do you want to run a heating indicator ?
n



      heat transfer method

 options     1.  hemisphere stagnation point
             2.  cato/johnson swept cylinder
             3.  eckert ref. enthalpy flat plate method
             4.  eckert/spaulding-chi flat plate method
             5.  boeing rho-mu flat plate method
             6.  beckwith/gallagher swept cylinder method
             7.  boeing rho-mu swept cylinder method
             8.  lees/detra-hidalgo hemisphere distribution
             9.  leeside orbiter heating
            10.  flap reattachment heating
            11.  fin-plate peak interference heating
            12.  brake payload impingement heating
```

Figure 1: Sample screenshot of a PREMIN menu.

The development language for MINIVER 2 is C#. In MINIVER 2, the PREMIN menus have been collapsed into categories similar to the ones mentioned in the above list. The MINIVER workflow has been adjusted such that there is a governing “project” which can be thought of as the object (e.g. launch vehicle) to be tested. A project contains “cases” which are body points on the object. Each case then possesses a “preprocessor data” set, which incorporates all of the information that PREMIN collected via its prompts. Figure 2 is a screenshot of the MINIVER 2 main screen, which shows the project structure presented in the form of a tree view. The user selects a preprocessor section to input data into, and the information box on the right updates to present the data for editing.

To assist with case creation, a few tools were created. The Trajectory Editor, as shown in Figure 3, provides a visual representation of the current trajectory in the editor. The Trajectory Editor functions within MINIVER or as a stand-alone program, allowing the user to open, edit, and save trajectories quickly. Unit systems are bound to the trajectory, allowing (for instance) a metric trajectory to be used in an English project; the trajectory values are converted automatically. The editor also supports importing Legacy trajectory files, that is, files that Legacy MINIVER saved and loaded for its use.

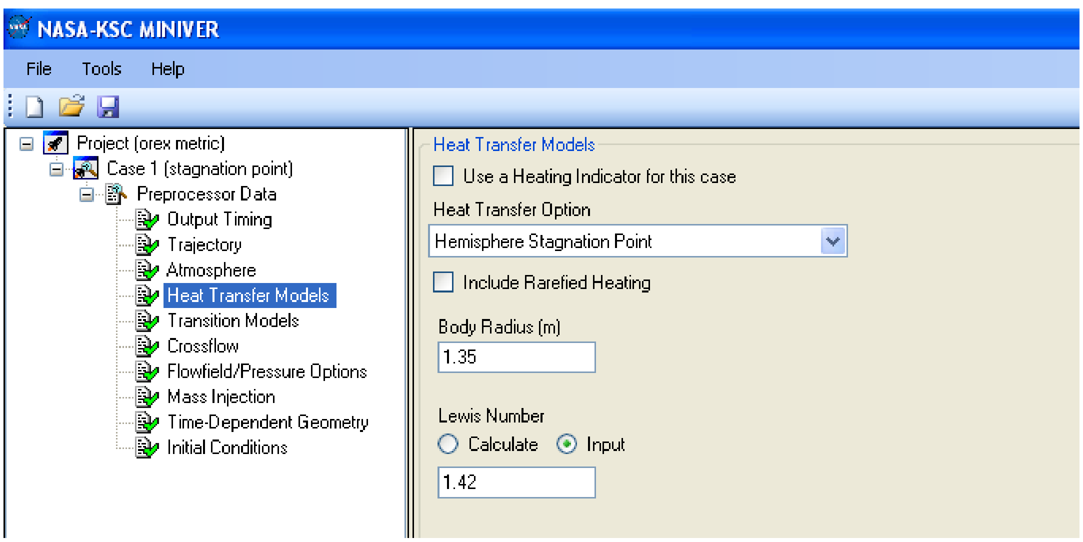

Figure 2: MINIVER 2.0 main screen.

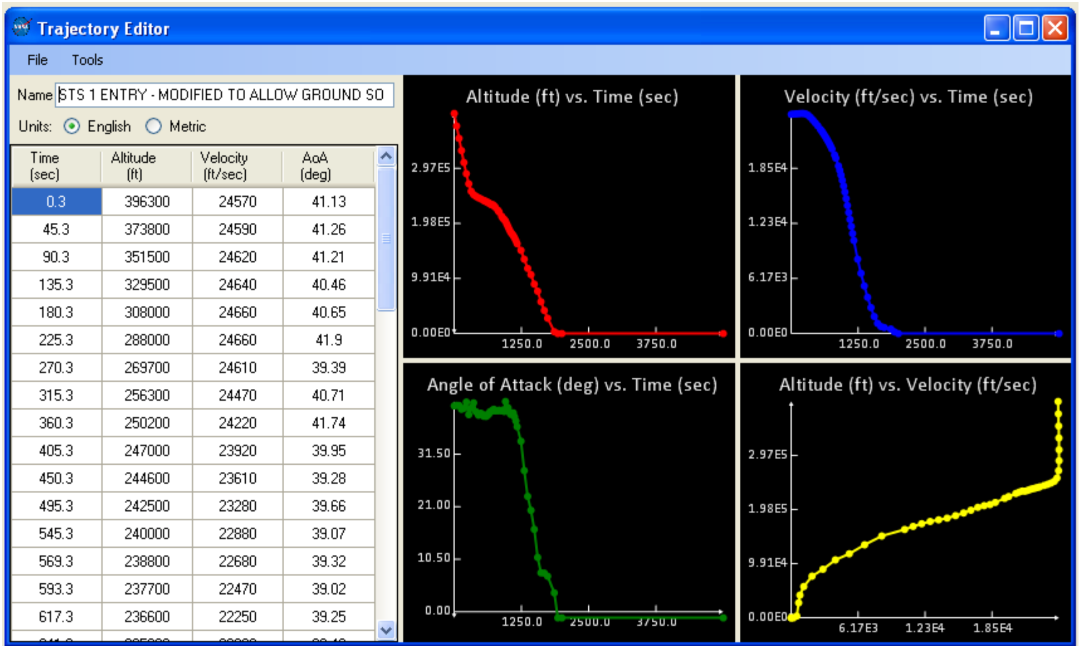

Figure 3: Trajectory Editor.

Other tools include a case copier utility (Figure 4) and a delimited file importer (Figure 5). The case copier allows the user to quickly copy sections of a case and apply them to other cases, such as when they utilize the same atmospheres or trajectories. The delimited file importer provides a means to quickly import bulk data sets, such as trajectories, C_P vs. Mach tables, time-dependent geometry tables, etc. The importer tool is designed as a modular utility: when invoked in code, the names of the columns are specified and the table is automatically populated. This helps to maximize code reuse.

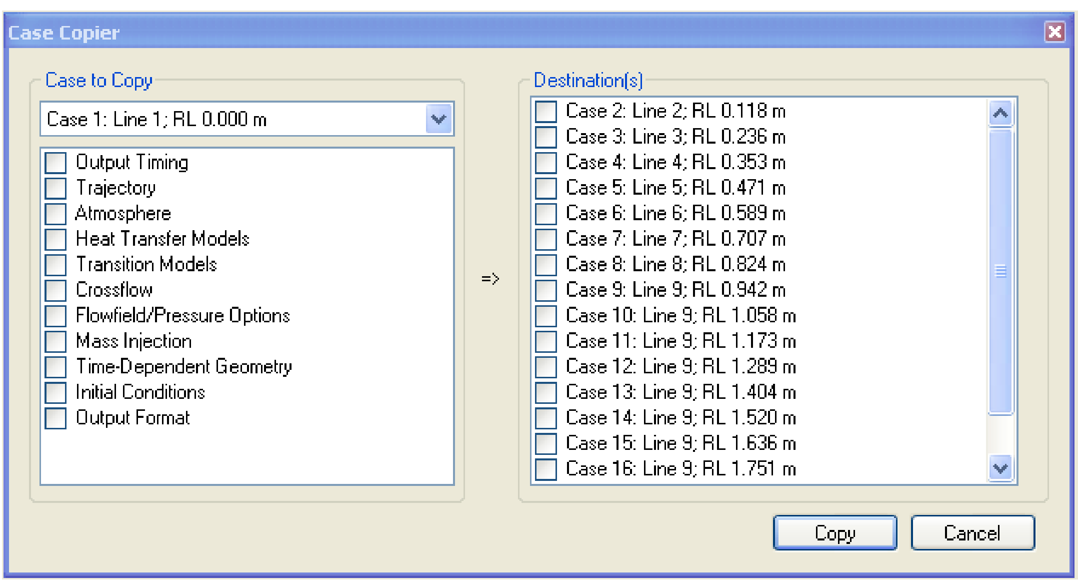

Figure 4: Case Copier.

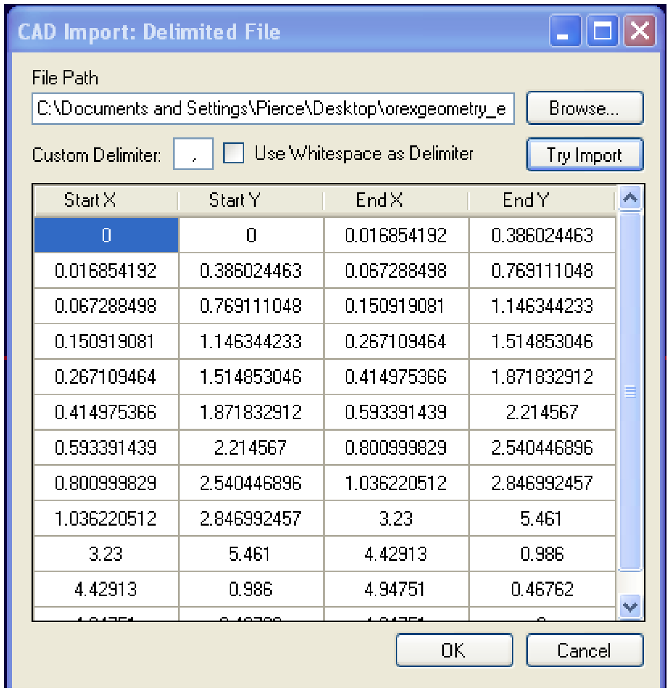

Figure 5: Delimited File Importer.

Overall, the MINIVER workflow has been improved by converting PREMIN into a graphical interface, as the user can quickly move between case sections, create cases from entered data, and use bulk data sets to speed up data entry. Case files can be saved and recalled using an XML format, in place of Legacy MINIVER's intermediate file which was fed into the LANMIN module.

<u>LANMIN Conversion</u>

LANMIN's processing routines were largely left the same, with most conversion efforts involving rewriting the routines to replace "go to" statements with if...else logic blocks. Whereas PREMIN and LANMIN were two separate modules in the Legacy version, MINIVER 2 combines both into the same program. The processor logic is available on a case-by-case basis (Figure 6) or can be done project-wide (Figure 7).

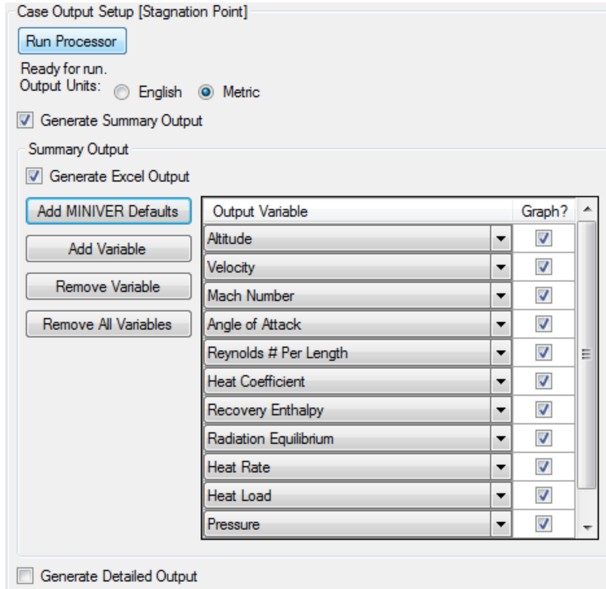

Figure 6: Single case processor and output setup.

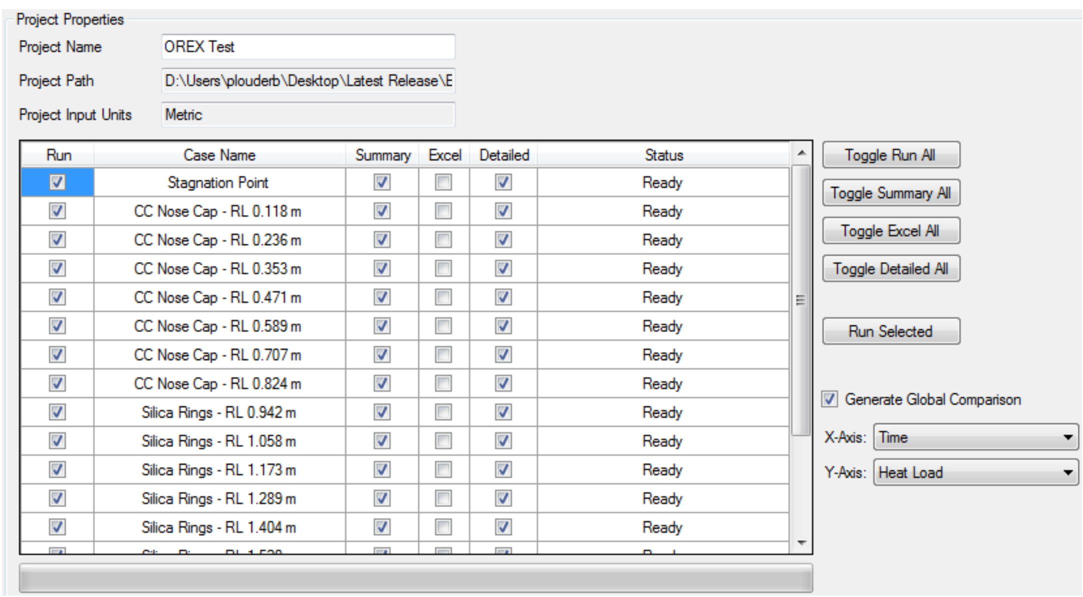

Figure 7: Project-wide case processing and output setup.

The single case processor allows the user to specify output units and generate the Legacy printouts referred to as “Summary” and “Detailed”. In addition, the user may create an Excel version of the Summary printout type, which will automatically create an Excel spreadsheet, format values, and generate graphs as specified. The Summary and Detailed formats maintain most of the formatting of their Legacy counterparts, with only minor formatting changes.

CAD Editor

A major addition to the first phase of the study was a basic CAD editor through which simple 2D geometries could be imported to create body point cases. Figure 8 demonstrates an example of the CAD Editor with the JAXA OREX vehicle. Geometry and trajectory information were taken from a paper by Gupta, Moss, and Price.[3] The CAD Editor understands geometry as a series of lines, defined by coordinate pairs for their start and end points. When a geometry is imported, the editor uses consecutive lines to create a cumulative running length. As points are generated, the MINIVER cases created for them will automatically populate with running length data as is relevant and, optionally, their angles can be used for heat transfer methods and flowfield / pressure options. Points can be generated in several manners, ranging from equal spacing to first / last lengths or ratios. A rectangular selection box capability is available to edit multiple points at once. Once finished, the CAD project can be saved for later or exported to MINIVER for conversion into a MINIVER project.

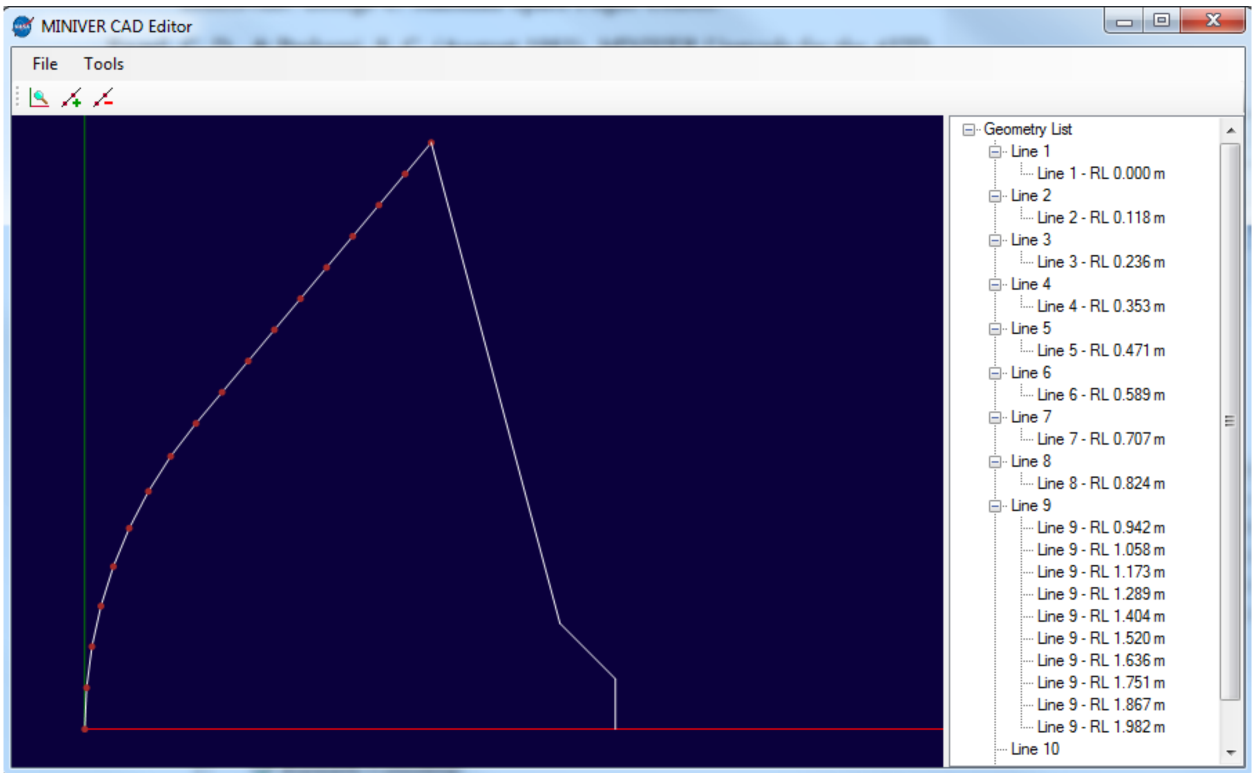

Figure 8: CAD Editor, using OREX geometry as an example.

OREX DATA

Most of the data for this particular test is reiterated from Gupta, Moss, and Price's paper.[3] The trajectory of a short period of the OREX re-entry is shown below in Table 1. The geometry of the OREX vehicle is given in Figure 9.

Table 1: OREX Trajectory[3]

Time (sec)	Altitude (km)	Velocity (m/sec)	Angle of Attack (deg)
7361.0	105.00	7451.00	0.0
7370.6	101.10	7454.65	0.0
7381.0	96.77	7456.30	0.0
7391.0	92.82	7454.10	0.0
7401.0	88.45	7444.30	0.0
7411.5	84.01	7415.90	0.0
7421.5	79.90	7360.20	0.0
7431.5	75.81	7245.70	0.0
7441.5	71.73	7049.20	0.0
7451.5	67.66	6720.30	0.0
7461.5	63.60	6223.40	0.0
7471.5	59.60	5561.60	0.0
7481.5	55.74	4759.10	0.0
7491.5	51.99	3873.40	0.0
7501.5	48.40	3000.00	0.0

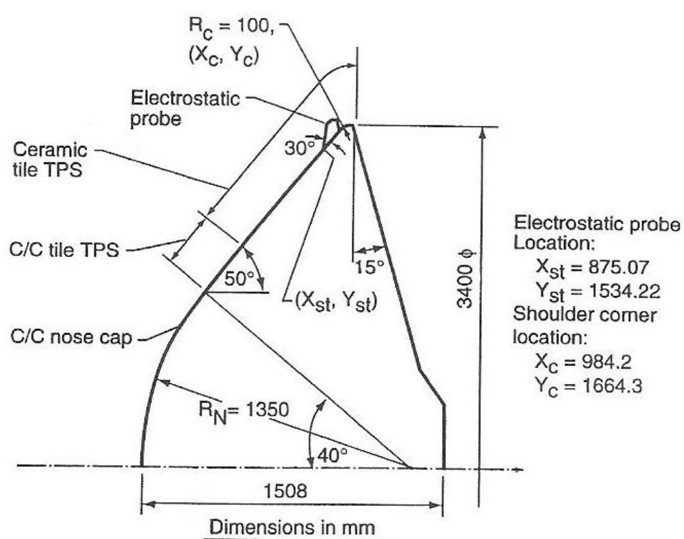

Figure 9: OREX geometry.[3]

Utilizing the given geometry, a series of lines were created for use in the CAD Editor. In the case of the C/C nose cap, the geometry was approximated with 8 lines, each spanning 5° of the 40° total for the cap geometry. These lines are defined in Table 2.

Table 2: OREX Geometric Data for the MINIVER CAD Editor

Start X (m)	Start Y (m)	End X (m)	End Y (m)
0.000000	0.000000	0.005137	0.117660
0.005137	0.117660	0.020510	0.234425
0.020510	0.234425	0.046000	0.349406
0.046000	0.349406	0.081414	0.461727
0.081414	0.461727	0.126484	0.570535
0.126484	0.570535	0.180866	0.675000
0.180866	0.675000	0.244145	0.774328
0.244145	0.774328	0.315840	0.867763
0.315840	0.867763	0.984504	1.664513
0.984504	1.664513	1.350000	0.300533
1.350000	0.300533	1.508000	0.142531
1.508000	0.142531	1.508000	0.000000

For this test case, the 1962 U.S. Standard Atmosphere was used as an approximation. Heat transfer methods were broken up into Hemisphere Stagnation Point at the stagnation point, Lees/Detra/Hidalgo Hemisphere on the spherical nose cap, and Eckert Reference Enthalpy Flat Plate for the remainder of the forebody, using Mangler transformation values to convert from flat plate to cone.

RESULTS

Only the stagnation point of the OREX vehicle was instrumented to acquire heat flux data. A comparison of MINIVER's output to this flight data is seen in Figure 10, with the MINIVER results overlaying a chart as found in Hirschel and Weiland's book, *Selected Aerothermodynamic Design Problems of Hypersonic Flight Vehicles*.[4] Gupta, Moss, and Price perform Viscous Shock Layer simulations for the rest of the forebody based on the stagnation point data. Their results serve as the overlay to Figure 11 and Figure 12, providing comparison to the MINIVER output data.[3]

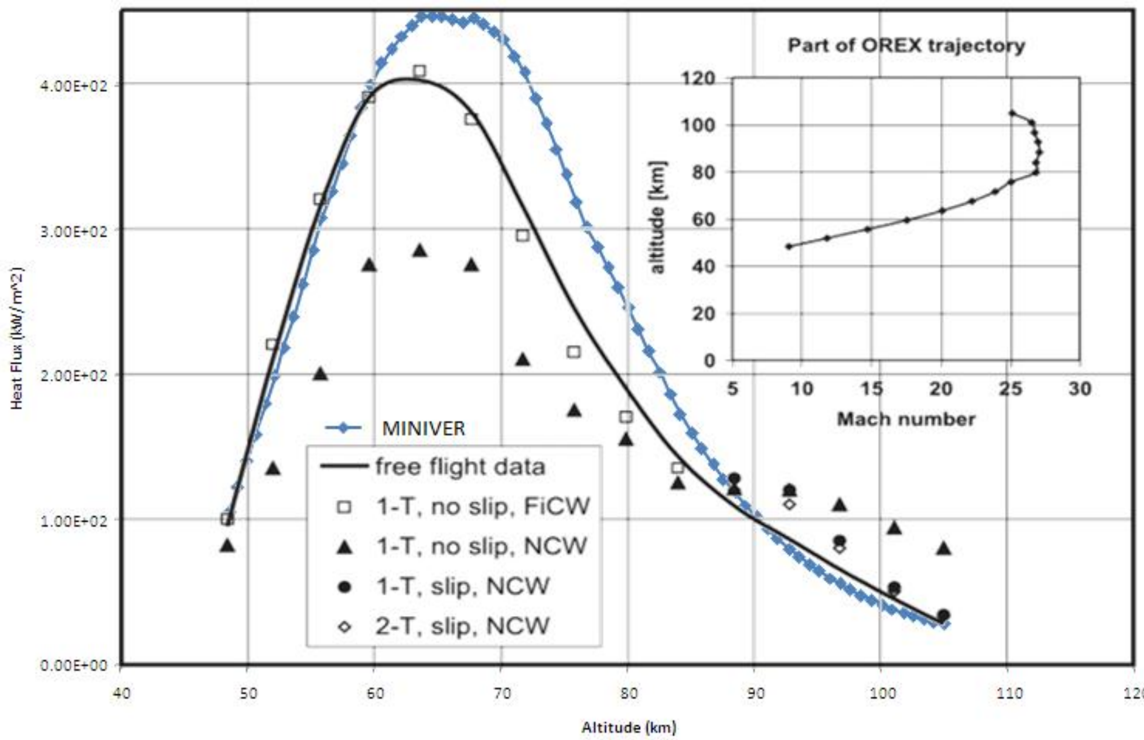

Figure 10: OREX stagnation point flight data comparison (plot overlay via Hirschel & Weiland)[4]

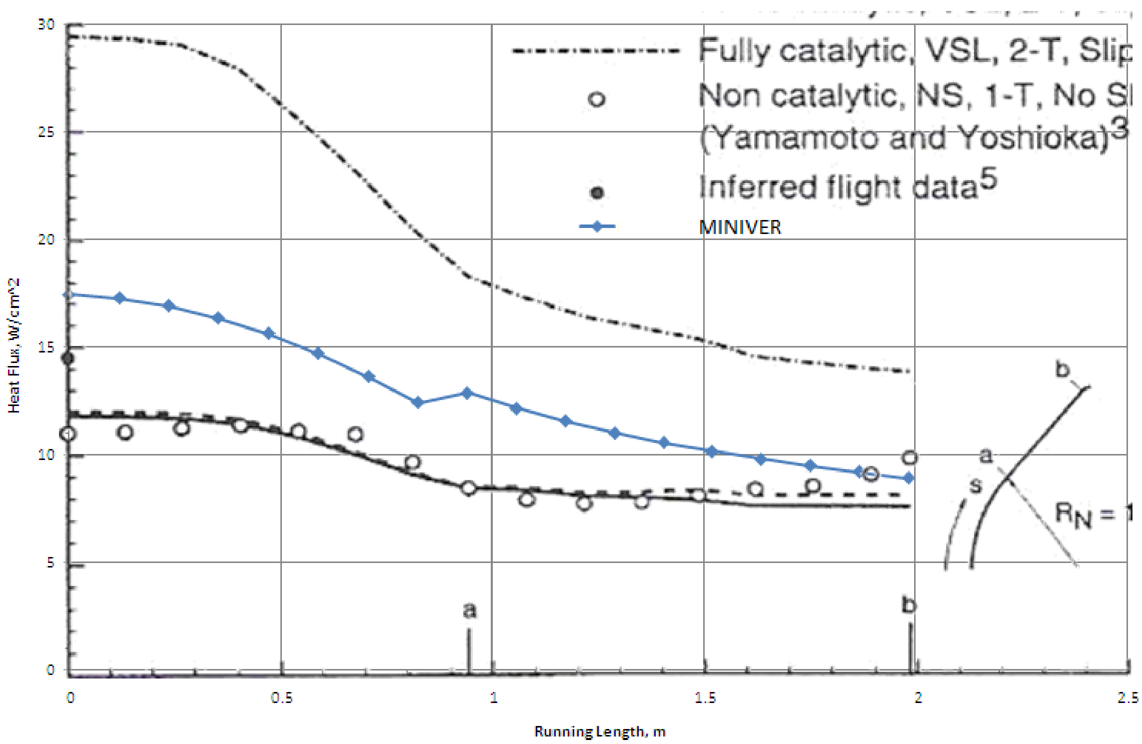

Figure 11: OREX forebody heat rate at 84.01 km; MINIVER comparison to VSL calculations (plot overlay via Gupta, Moss, and Price)[3]

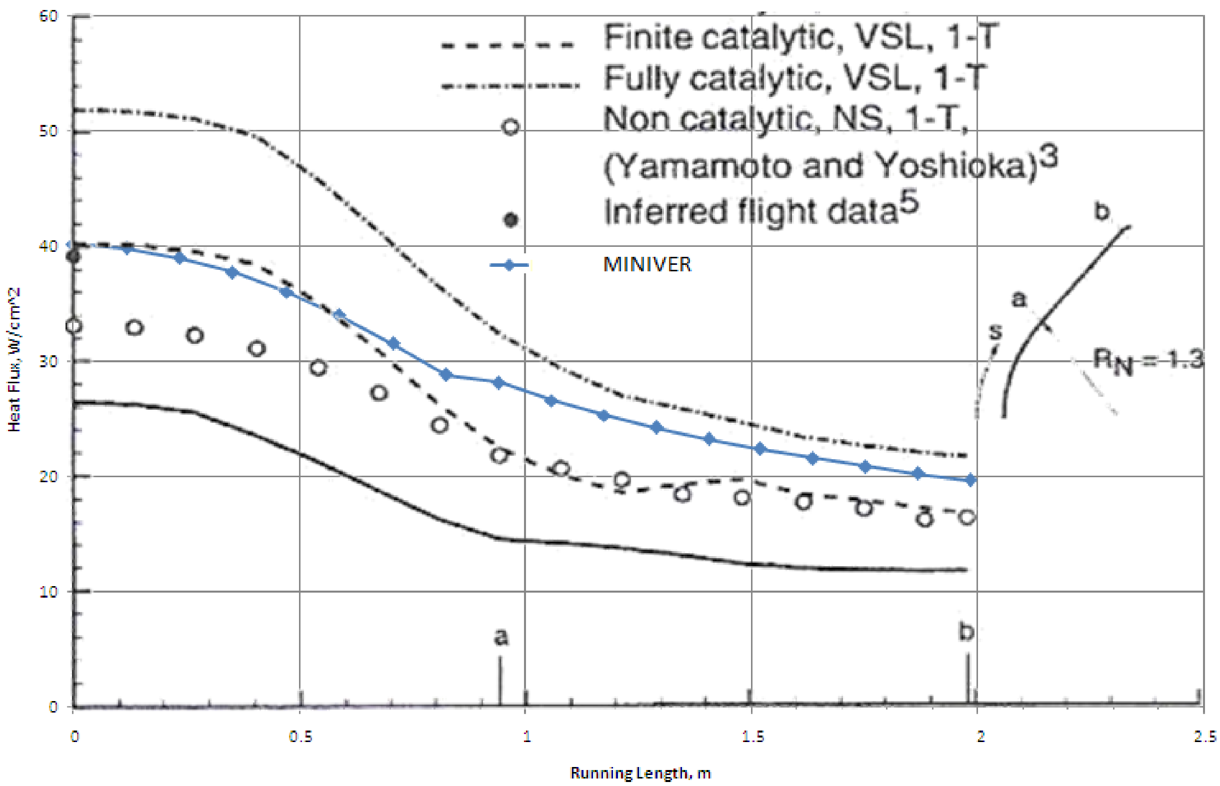

Figure 12: OREX forebody heat rate at 59.60 km; MINIVER comparison to VSL calculations (plot overlay via Gupta, Moss, and Price)[3]

CONCLUSION

MINIVER has received several updates as part of an ongoing effort to modernize the interface and improve the software as a whole. The new interface is capable of providing fast, intuitive pre-processing and processing for new and old users alike, and new utilities are available to assist the user in performing pre-processor tasks. Results demonstrate that MINIVER still provides a strong, supportive role for swift estimation of aerothermal heating environments. As part of the next phase of development, MINIVER will continue to be enhanced. Features will be added as per the need of engineers who will be using the software. In addition, the goal of the next phase is to establish a methodology where MINIVER output data can be quickly exported to C&R Tech's SINDA and Thermal Desktop™ software packages.

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[2] Engel, C.D., and Schmitz, C.P. (August 1983). *MINIVER Upgrade for the AVID System, Vol 2: LANMIN Input Guide.* NASA CR-172213.

[3] Gupta, R.N., Moss, J.N., and Price, J.M. (1997). Assessment of Thermochemical Nonequilibrium and Slip Effects for Orbital Re-Entry Experiment. *Journal of Thermophysics and Heat Transfer, 11*(4)

[4] Hirschel, E. H., and Weiland, C. *Selected Aerothermodynamic Design Problems of Hypersonic Flight Vehicles*.

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