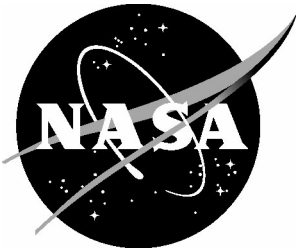


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Imaging for Hypersonic Experimental Aeroheating Testing (IHEAT) version 4.0: User Manual

*Michelle L. Mason and Shann J. Rufer
Langley Research Center, Hampton, Virginia*

November 2018

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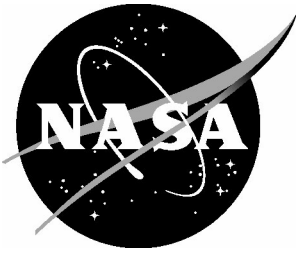
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*Michelle L. Mason and Shann J. Rufer
Langley Research Center, Hampton, Virginia*

National Aeronautics and Space
Administration

Langley Research Center
Hampton, Virginia 23681-2199

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Abstract

The Imaging for Hypersonic Experimental Aeroheating Testing (IHEAT) v4.0 thermography data processing code obtains global heat transfer information from wind tunnel models tested in the NASA Langley Aerothermodynamics Laboratory (LAL) facilities. This user manual describes the purpose and the features of IHEAT. A tutorial and a flow chart are included that describe the tools and detail the procedural steps of the phosphor thermography data reduction process implemented in IHEAT v4.0.

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Nomenclature

Symbols

x	Distance along model in longitudinal direction for axial cuts
y	Distance along model in lateral direction for longitudinal cuts
L	Reference longitudinal length
y_{ref}	Reference lateral length

Acronyms

CCD	charge-coupled device
ETB	edit text box
GUI	graphical user interface
IHEAT	Imaging for Hypersonic Experimental Aeroheating Testing
IR	infrared radiation
ITB	insert text box
LAL	Langley Aerothermodynamics Laboratory
LaRC	Langley Research Center
LUT	look-up table
ROI	region of interest

1. Introduction

The IHEAT v4.0 software is a data reduction code for global thermography data acquired in the NASA Langley Aerothermodynamics Laboratory (LAL) hypersonic wind tunnels. IHEAT uses red and green color-intensity data from two-dimensional images of wind tunnel models to compute temperatures and heat-transfer rates using a semi-infinite, one-dimensional heat transfer approximation at each image pixel. Multiple automated tools in IHEAT v4.0 decrease the time required to reduce the data from a phosphor thermography wind tunnel run. Data at one or all of the image pixel locations can be exported to computer files for further analysis.

The prior version of IHEAT, v3.2, was written in PV-WAVE[®] (now owned by Rogue Wave[®] Software) in 1994 and was limited in functionality to fit within the memory constraints of the available computers at the time. IHEAT v4.0 is written in MATLAB[®] by MathWorks[®] and contains several new features that leverage the increase in available memory of the current computers. A *Piecewise* tool permits the user to extract data along a segmented line cut that can follow interesting features in the image better than the single, straight line cuts that were possible with the legacy *Length* and *Profile* tools. The new *Load Run* and *Batch* tools facilitate batch processing by loading in all of the input files and images for a run at the same time. *Load Run* permits the user to process the available run images manually, while *Batch* automatically saves heat transfer data from all of the images based on the analysis previously performed on a single frame. IHEAT v4.0 also can automatically calculate the temporal collapse of reference line cuts from the time history heating data for a run to indicate the appropriate frame to reduce for each run.

The IHEAT v4.0 source code was compiled into a standalone executable file that can be accessed remotely from several computers with different operating systems, simultaneously. The software is run through the MATLAB[®] Compiler Runtime engine, and therefore, IHEAT does not require a software license to run. Any software commands executed in the IHEAT v4.0 code will not affect other similar applications running on the same machine. Similarly, changes to the parent software do not affect a compiled code. These features of IHEAT v4.0 are improvements over the legacy v3.2 code, which required regular maintenance to avoid losing functionality as the PV-WAVE[®] programming language was upgraded.

2. Purpose of IHEAT

References 1, 2 and 3 describe the phosphor thermography data acquisition and reduction process used during aeroheating tests in the LAL hypersonic wind tunnel facilities. During a phosphor thermography wind tunnel run, the phosphor coating on a ceramic model fluoresces when the coating is illuminated by ultraviolet lights. A digital 3-color (red, green, and blue) Charge Coupled Device (3-CCD) camera is used to take pictures of the model and these images are loaded into IHEAT v4.0 for analysis. Red and green intensity values at each pixel are used to calculate the model's surface temperature at a given instant in time. Temperature contours are displayed in the IHEAT v4.0 window with a representative color map. Heat transfer coefficients are then computed at each pixel for a given time, based upon prerun and run-time images, using the approximations listed in references 1–3. These heat transfer coefficients are displayed either as dimensional values or nondimensionalized with respect to the Fay-Riddell stagnation heat transfer coefficient for a user-specified hemispherical nose radius.

Section 3 of this user manual is comprised of an overview of the IHEAT v4.0 tools, followed by three subsections that describe how IHEAT v4.0 is used to reduce the LAL phosphor thermography data. The tutorial in section 3.2 offers a brief description of each of the tools included in IHEAT v4.0. The flow chart in section 3.3 provides a step-by-step explanation of how aeroheating data can be reduced following a wind tunnel run in the LAL facilities. References 4 and 5 (which are internal reports) explain the phosphor thermography data acquisition and reduction processes in more detail. Subsection 3.4 and section 4 discuss best practices for reducing phosphor thermography data. Finally, section 5 describes planned modifications to IHEAT v4.0 that will be included in future releases of the software.

3. IHEAT Overview

IHEAT v4.0 runs on a LINUX operating system and is accessible remotely from Windows, Linux or Macintosh operating systems. Several tools are available in IHEAT v4.0 to reduce data obtained during phosphor thermography tests. These tools (typeset in italics) are grouped according to their primary functions and described briefly in section 3.1. A detailed tutorial in section 3.2 explains the use of each of these IHEAT v4.0 tools with images of the IHEAT graphical user interfaces (GUIs) as the different steps are performed. Several paths are available to process data from a phosphor thermography run in IHEAT v4.0; however, a typical data reduction process is demonstrated in the flow chart in section 3.3. Instructions for accessing the IHEAT v4.0 software are provided in the first two pages of the flow chart. Section 3.4 provides guidelines to avoid problems with running IHEAT v4.0 incorrectly that were discovered during beta testing.

3.1. Overview of IHEAT v4.0 Tools

The most relevant tools in IHEAT v4.0 are briefly introduced in this section of the user manual. These tools and others are described in more detail in the tutorial and flow chart in subsequent sections.

3.1.1. Legacy file processing tools

Data from wind tunnel runs conducted in the LAL facilities prior to 2015 and originally processed using the older version of IHEAT can be re-reduced in IHEAT v4.0, as necessary. The format of the input files needed to run IHEAT has changed between the legacy versions and IHEAT v4.0. Thus, the *Convert Files* tools allow the user to easily convert the set-up file, flow conditions files, and position gauge file into a format that can be read into IHEAT v4.0. These input files can be loaded into IHEAT using the *Load Set-up File*, *Load Flow Conditions File*, and *Load Position Gauge File* tools. The *Load LUT* tool has been added to IHEAT v4.0 to allow the user to select a specific look-up table (LUT) to load into IHEAT during the calibration of a new phosphor mix (without changing the set-up file for that run); however, the user should exercise caution to avoid using the *Load LUT* tool to specify the wrong LUT for the acquired data set.

3.1.2. Image labeling tools

Images in IHEAT v4.0 can be labeled as preliminary, proprietary, or sensitive using various standard and user-defined specifications. Standard image and color bar titles are automatically generated based on the test name in the set-up file for a run, and these titles can be modified using the *Image Titles* tool. The units of the temperature image data can be toggled between English (°F) and metric units (°C) via the *Image Units* tool.

3.1.3. Data extraction tools

Image data can be analyzed at every pixel using either the “*impixelinfo*” or the “*datacursor*” built-in software tools (for the current image on display), or using the *Data* tool (which provides information at that pixel location about all of the images that are currently stored in memory). Data can be extracted from multiple points along a single straight line drawn on the image using either the *Length* or the *Profile* tools, from a grid of multiple straight lines using the *Auto Profile* tool, or from a segmented line cut using the *Piecewise* tool. By toggling on the *Activate Line Cuts Menu*,

the end points of the straight lines easily can be duplicated from image to image within a run's entire temporal data set.

3.1.4. Image display tools

IHEAT v4.0 contains eighteen color map choices that can be used to view different flow, heating or geometric features on a model that could be visually obscured when the standard rainbow color map is implemented by default. The *Temperature Filter* also can be toggled on to reduce the noise in the image data or off to allow the user to examine the image for the possibility of very narrow features that could be blurred by the application of the median filter with a 5x5-pixel neighborhood. The user easily can switch between the prerun temperature, run temperature, heat transfer and uncertainty images in the drop-down *View* menu (or in additional drop-down menus for *Batch* or *Load Run* operations). The *Zoom In* and *Zoom Out* tools allow the user to magnify a smaller region of the model, and the *Pan* tool can be used to translate the zoomed image.

3.1.5. Data processing and reduction tools

The *Compute Heat Transfer* menu allows the user to determine the heat transfer mapping for a selected prerun and run temperature image pair for either a fused silica ceramic or a Macor[®] wind tunnel model by toggling material buttons. If necessary, the *Shift Run Image* tool can be used to align the run temperature image with the prerun temperature image if the model location changed due to the sting bending in the tunnel during the run. Prior to computing the heat transfer data, the user can use the *Check PreRun Temperature* tool to verify the prerun temperature image displays uniform model temperature data that compares well with the temperature measured by a thermocouple either in the test section or attached to the back of the wind tunnel model.

The percent uncertainty in heating at each pixel on the model can be computed for runs in either the 20-Inch Mach 6 or the 31-Inch Mach 10 Tunnels using the *Run Uncertainty* tool in the *View* menu. Extraneous data in the images (due to reflections from the tunnel windows, for example) can be hidden using the *Mask* tool, which applies the same masked region to the intensity, temperature, heat transfer and uncertainty images in the run. The *Undo All Mask Edits* tool restores the image regions that were hidden using the *Mask* tool. Regions on the model also can be queried using the *Stats* tool to determine the number of points, the maximum, minimum and mean values, and the standard deviation of the points in the region.

By automating several steps in the process, the phosphor thermography data from a run can be reduced more efficiently. The *Load Run* tool facilitates batch processing by allowing the user to load in all of the input files and images for a run at the same time. The *Save All* function allows the user to save the full set of reduced data from a *Load Run* operation without needing to save each image individually. The *Batch* tool also automatically computes the heat-transfer mapping that corresponds to each of the temperature images in a run folder, based on how a single image was analyzed, and saves the appropriate data files to folders. The tutorial in the next section provides more detailed insight into how these and other tools are used in IHEAT v4.0.

3.2. IHEAT v4.0 Tutorial

This tutorial describes the features of IHEAT v4.0. In the first section of this tutorial, the menu items are discussed. Next, the image tools positioned in the left column of the user interface are explained. Finally, the *Batch* and the *Shift Run Image* operations on the right side of the GUI are

described. Grayed-out options that are not discussed in this tutorial (e.g., extrapolation to flight) are in the alpha testing phase and will be beta-tested prior to an update to the IHEAT software.

3.2.1. File Menu:

1. Under *File > New*, the following three options appear (as shown in figure 1): *New Test*, *New Run*, and *New Batch*. The difference between these three options is as follows:
 - A. *New Test*: Clears all of the current run variables from memory.
 - B. *New Run*: Clears the current run variables from memory, excluding the variables from the set-up file.
 - C. *New Batch*:
 1. Clears the current run variables from memory, excluding the variables from the *Auto Profile* analysis data.
 2. The *Run Folder* name used to determine where to perform the *Batch* operation does not change when *New Batch* is selected. Thus, the user can change the path and folder name manually either before or after selecting *New Batch* (refer to the *Load Run* section on page 6 for instructions on how to change folders).

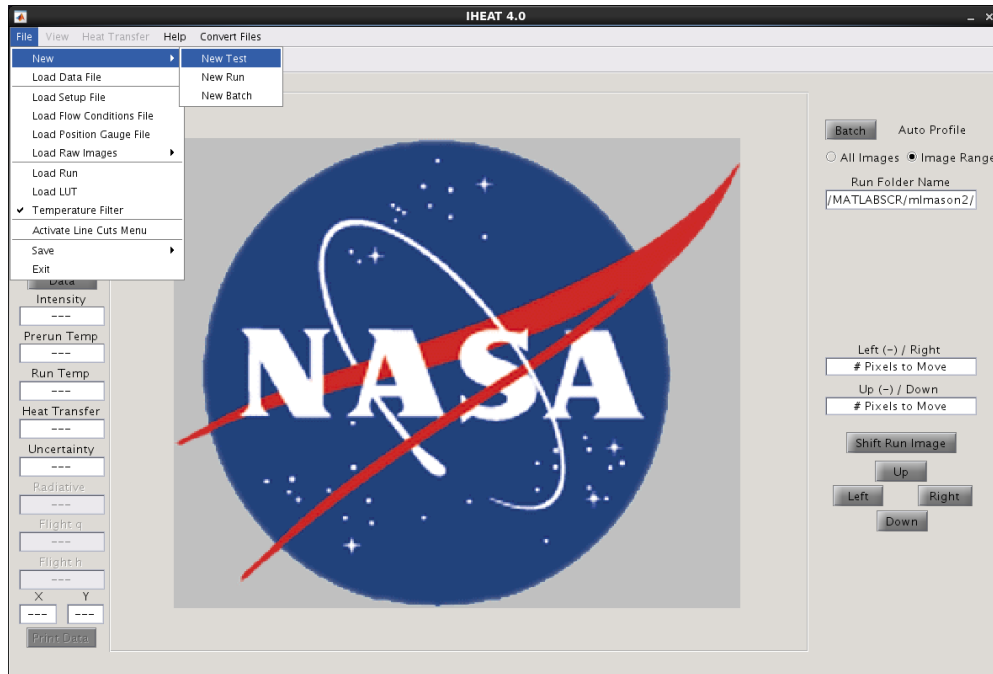


Figure 1: File Menu, New.

2. The next option under *File* is *Load Data File*. This menu item is used to load a saved phosphor thermography run into the IHEAT v4.0 software.
3. The following three items in the *File* menu in figure 1 are the *Load Setup File*, *Load Flow Conditions File* and *Load Position Gauge File* options. These options are used to bring in the required information about the facility and the flow conditions to reduce a new phosphor run. These files can be loaded into the software in any order. When a new file is loaded into the software, the variables extracted previously from a file of the same type are overwritten. The file name extension for each of these file types is as follows: set-up files

end in “.ihs”, flow conditions files end in “.tekflw”, and position gauge files end in “.tektxt”. If a required file is not loaded into the software before the *Compute Heat Transfer* button is selected, an error message appears that requests the missing information.

- Under *File > Load Raw Images* in figure 2, two options appear: *Load PreRun Image* and *Load Run Image*. The calculated temperatures are shown for each of these images. When either image is loaded into the software, the LUT (specified by the set-up file or in the *Load LUT* tool) is applied and the image appears in the middle box in figure 2, with an appropriate title above and color bar to the right of the image. These images can be loaded into IHEAT in either order. After both images are loaded, a black border appears around the run image to signify the edge of the prerun image for alignment purposes.

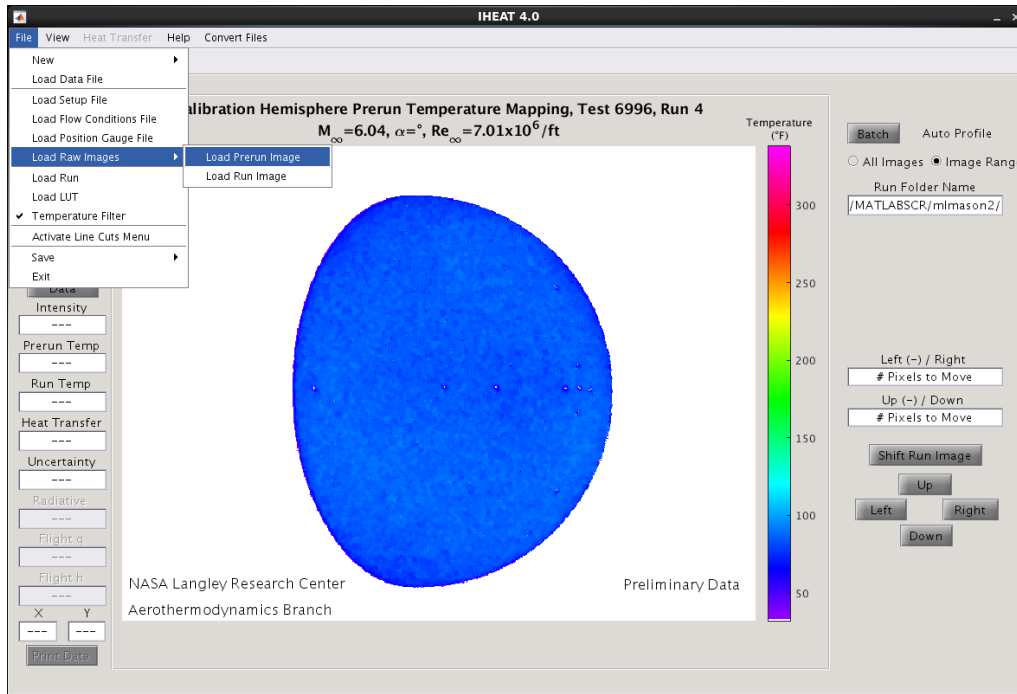


Figure 2: File Menu, Load Raw Images.

- A new option in IHEAT v4.0 is *File > Load Run*. To change the name of the run folder to access different files for the *Load Run* command, left click in the text box labeled “Run Folder Name” in the upper right corner of the main GUI and press “Enter/Return.” A dialog box appears that asks the user to select the run folder. Once the correct folder is specified, click open, and a message box will appear that shows the name of the new run folder.

After specifying the appropriate run folder, click *Load Run*; at this point, the menus on the right side of the main GUI window will change to include those shown in figure 3. If another run is already open, the user is prompted to select *New > Test*, *Run* or *Batch* prior to *Load Run*. If set-up and position gauge files are located in the run folder, these files are loaded into IHEAT v4.0 (provided the run folder only contains one .ihs file). If the set-up file is in a different directory, a pop-up message asks the user to specify the directory that contains the set-up file so the file can be loaded. If the number of .tekflw files matches or exceeds the number of run images in the folder, the flow conditions files are loaded into a

drop-down menu, organized by the run time in each file. *Load Run* also loads in the pre-run image as long as one, and only one, image in the run folder contains a capital “P” in the file name. All of the remaining *.tif* files in the run folder are loaded in as run images, and organized by frame number in the lower drop-down menu shown in figure 3.

The first frame in the lower menu is paired with the appropriate flow conditions file to show the initial run temperature image after the *Load Run* operation. The images in the run temperature drop-down menu can be shifted after loading in the files, and the temperature filter for these images can be toggled on or off. The same shifting is applied to each image selected in the drop-down menu, unless the user manually changes the shifting amount when a new image is selected.

When *Load Run* is implemented, the user must exercise caution in computing heat transfer results to avoid overwriting data. Only one heat transfer image is stored in memory at a time during a manual heat transfer analysis process (not a *Batch* operation), so the heat transfer data is overwritten each time the *Compute Heat Transfer* button is clicked for a selected flow conditions file and run frame. If the user selects *View > Change Image > Heat Transfer*, the image displayed in the main GUI will correspond to the most recently computed heat transfer data, which may differ from the time listed for the flow conditions file or the current frame in the drop-down menus. Each time the heat transfer image is accessed during a *Load Run* operation, the software displays the frame number along the *x*-axis of the image to remind the user which conditions correspond to the displayed heat transfer data.

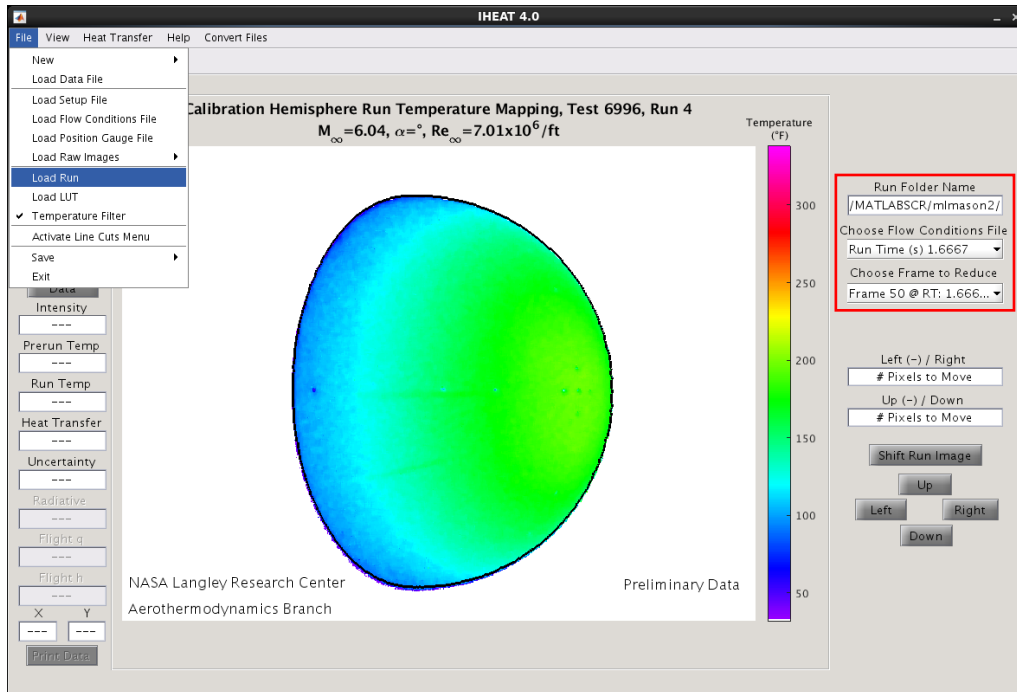


Figure 3: File Menu, Load Run.

- The next item in the *File* menu in figure 3 is *Load LUT* in which the user can load in a different LUT file than the one specified in the set-up file. The LUT file must be a *.dat* file.

Two header lines are included at the top of this file. The most recently loaded LUT file overwrites the LUT file data previously loaded into IHEAT v4.0.

7. Under *File > Temperature Filter*, the user has the option to toggle the temperature filter on or off any time prior to computing the heat transfer. When applied, a median filter with a 5x5 neighborhood of pixels reduces the “salt-and-pepper” noise in the pixels of the image. A Sobel filter enhances the edges in the image and ensures the median filter is not applied in regions with strong gradients. Closing the *Temperature Filter* tool updates the visible image (excluding previously computed heat transfer data) to reflect the filter settings. A check mark appears beside the *Temperature Filter* menu item if the filter is on.
8. Another feature in the *File* menu is the *Activate Line Cuts Menu*. When this menu is toggled on, a check mark appears beside the item in the *File* menu, and the user interface changes as indicated by the red box in figure 4. This item allows the user to type in the (x, y) pixel locations for the endpoints of a line cut. When the user specifies two x values and two y values in the text boxes, the slope of the line is automatically calculated and displayed. After a line is specified, the reset button can be used to change the five text boxes back to the default strings shown in figure 4.

The *Activate Line Cuts Menu* option can be used in conjunction with the *Length* or *Profile* image tools discussed later. After specifying the end points in the text boxes of this menu, if the user enters one of these two line cut tools, a line will appear on the image in the specified location. The end points can be changed while the line cut tool is running, and the position of the line on the image will change accordingly. Prior to following the prompts in the line cut tool to view the data from the line cut, the user must first click somewhere inside the image when these text boxes are in use.

The pixel values of the endpoints of the line cannot be less than one or exceed the maximum pixel values in the horizontal and vertical directions for the given image. If a value is entered that is outside this range, the pixel value of the nearest edge on the image automatically replaces the given value. When the *Activate Line Cuts Menu* item is toggled off, the strings in the text boxes revert to the default values, and the buttons used in this tool are hidden. Otherwise, the values are retained until the reset button is clicked.

9. The next category in the *File* menu is the *Save* button, which has eight options: *Data*, *ASCII Heating Data*, *ASCII All Data*, *Heating MAT File*, *JPEG*, *PNG*, and *TIF*, *All Frames*.
 - A. *File > Save > Data*: For individual frame analyses, this option saves the progress on the data reduction, so the data file can be reloaded into IHEAT v4.0 to continue the reduction at a later time. In *Batch* operations, all of the data that corresponds to the heat transfer image that was most recently selected is saved using this tool. In *Load Run* operations, the most recently selected flow conditions file and run temperature frame are saved using this tool, along with the other data stored in memory.
 - B. *File > Save > ASCII Heating Data*: This option saves the heat transfer data at each pixel location to a **.dat** file that can be opened in external software.

- C. *File > Save > ASCII All Data*: This option saves the green and red intensity, prerun temperature, run temperature, and heat transfer data at each pixel location to a **.dat** file that can be opened in external software.
- D. *File > Save > Heating MAT File*: This option saves the heat transfer data at each pixel location to a **.mat** file.
- E. *File > Save > JPEG/PNG/TIF*: These options will save the current image in the middle box of the overall IHEAT v4.0 user interface in the specified format.
- F. *File > Save > All Frames*: For a *Load Run* operation, this item saves all of the images and parameters loaded into memory. Note: This option is disabled after a *Batch* operation because all of the frames are automatically saved during a *Batch* process.

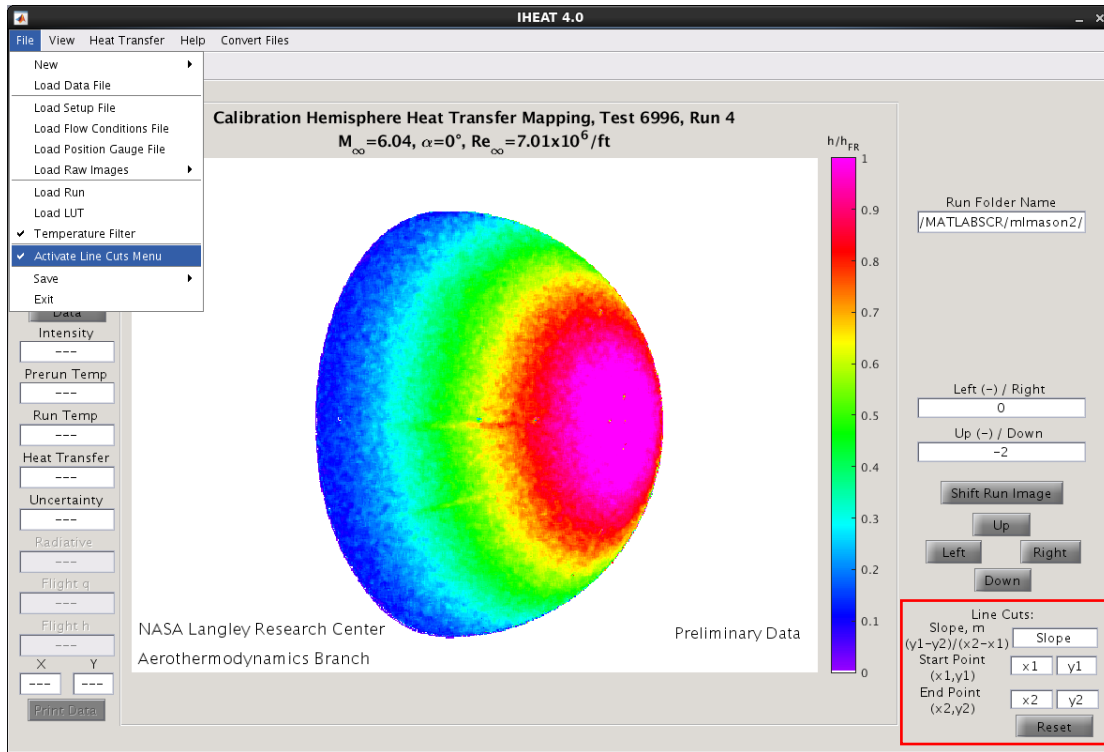


Figure 4: File Menu, Activate Line Cuts Menu.

10. The *Exit* menu item at the bottom of the *File* menu or the “x” in the upper right corner of the IHEAT v4.0 GUI close the software. Both methods open a dialog box to ask the user whether the IHEAT v4.0 software should be closed, since unsaved data will be lost when the GUI closes.

3.2.2. View Menu:

1. Using *View > Refresh Image*, the user has the option to refresh the image shown in the middle box of the IHEAT v4.0 GUI. This function will remove a line from a *Length, Profile*, or *Piecewise* line cut, the grid from an *Auto Profile* analysis, or points from a *Data* operation that were not hidden when those tools were exited. This function will also show the most recent changes applied by the *Mask* or *Undo Mask* operations, and will apply the currently selected color map and temperature filter. Most changes to the image should be applied automatically, but the *Refresh* button can be used as needed.

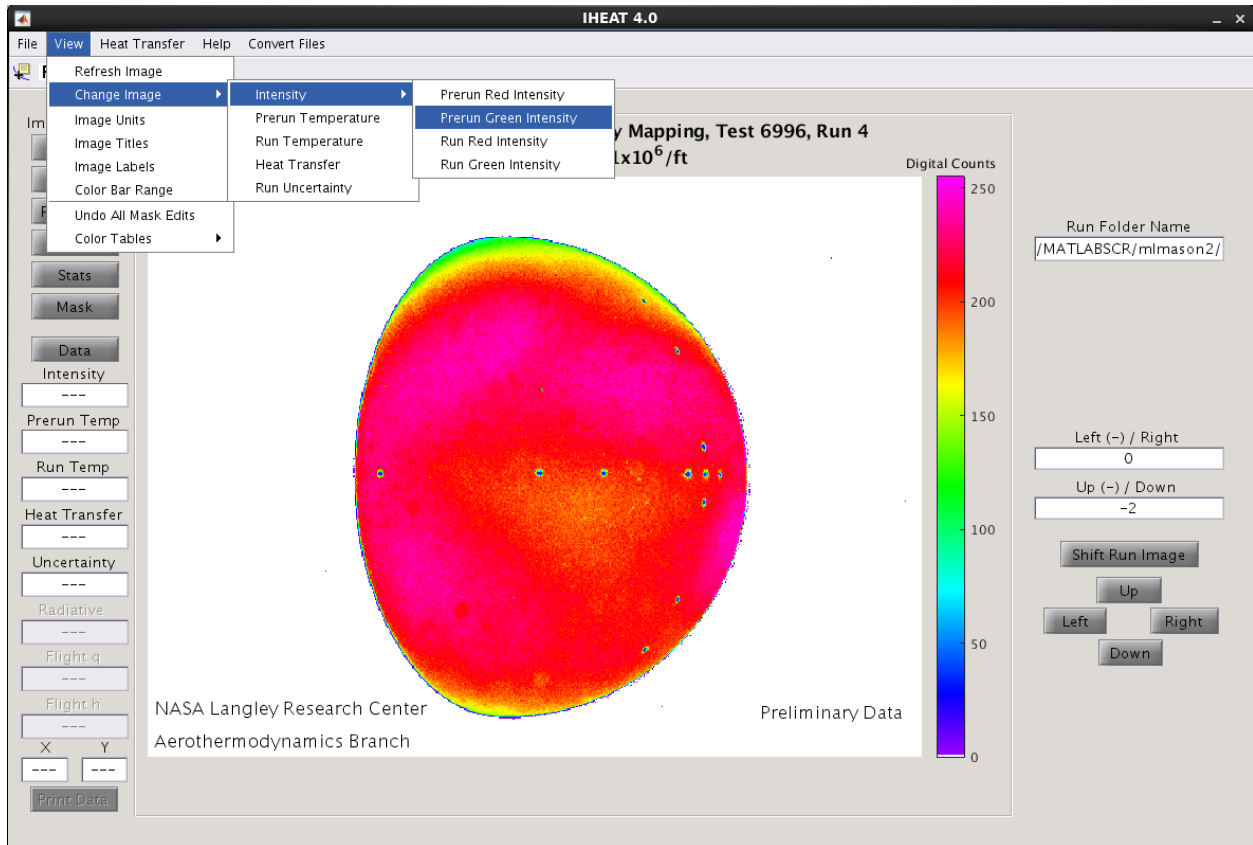


Figure 5: View Menu, Change Image.

2. The next item on the *View* menu is *Change Image*. The options under this item change from the eight items in figure 5 for an individual frame, to five items if *Load Run* is used, or four items if *Batch* is used. The intensity images are the red or green color planes of the images. The following outline shows which options are available for the three types of data processing.
 - A. *View > Change Image > Intensity > Prerun Red Intensity/Prerun Green Intensity*: These options are both available for all three types of data reduction, since only one prerun image is used for a given run.
 - B. *View > Change Image > Intensity > Run Red Intensity/Run Green Intensity*: These two options are available for individual frame and *Load Run* analyses.
 - C. *View > Change Image > Prerun Temperature*: This option is available for all three types of data reduction. If the temperature filter is toggled on or off and the prerun image is selected, the appropriate change will be applied to the visible image.
 - D. *View > Change Image > Run Temperature*: This option is only for individual frame analyses since multiple run temperature images can be accessed from the drop-down menus after *Load Run* or *Batch* operations.
 - E. *View > Change Image > Heat Transfer*: This option is available during individual frame or *Load Run* data analyses. During *Load Run*, the most recently calculated heat transfer image is available, which may not correspond to the currently selected flow conditions and run image files in the drop-down menus, as discussed previously in the *Load Run* section.

- F. *View > Change Image > Run Uncertainty*: This option is available for all types of data reduction within IHEAT v4.0. The run uncertainty image shows the combined value of the individual root mean square uncertainty values at each pixel on the model.
3. Under *View > Image Units*, the user can switch between metric and English image units.
 4. Under *View > Image Titles*, the user can change the title listed above the image as well as the color bar title. Although the values of the Mach and Reynolds numbers and the nose radius cannot be changed, the user can choose whether these values are displayed in the title. The user must supply the angle of attack for the run. The yaw angle, flap deflection angle, and length Reynolds number also can be specified in this dialog box.
 5. The next item in the *View* menu is the *Image Labels* tool. When in use, the proprietary label is set up so that the company name precedes the word proprietary. The preliminary label is located in the lower right corner of the image until the user toggles the label off.
 6. The *Color Bar Range* tool in the *View* menu is used to change the scale on the color bar. The user can modify the default limit values for the different parameters, which are 0 to 255 for intensity images, 0° to 170° in Celsius or 32° to 338° in Fahrenheit for temperature images, 0 to 1 for nondimensional heat transfer images, and 0% to 100% for run uncertainty images. For the default “rainbow” color map, overscaled data is pink and off-scale data is white.
 7. The next item is *View > Undo All Mask Edits*. This menu item can be used to remove any masks applied to all the images in memory. The *Refresh* function is automatically called so that the previously masked regions on the current image (and other images stored in memory) are again visible as data when those images are viewed in the GUI or accessed in data calculations.
 8. Under *View > Color Tables*, the user can change the color map that is applied to the image. Certain flow features or attributes of the model (such as geometric characteristics or fiducial marks) are more easily distinguished when different color maps are used.

3.2.3. Heat Transfer Menu:

1. The only item on the IHEAT v4.0 *Heat Transfer* menu is *Compute Heat Transfer*. The whole prerun image is used to calculate the heat transfer data, correlating pixels on the model in the prerun temperature image to the same pixels on the model in the frames obtained during a run.
2. The *Compute Heat Transfer* tool (see figure 6) allows the user to choose between fused silica and Macor[®] as the material of the model. The *Reset* button is included in case the user changes parameters in the text boxes, but then decides to restore the default values obtained from the flow conditions file. The user can also choose whether to calculate non-dimensional or dimensional heat transfer coefficients by selecting the corresponding toggle buttons. The *Compute* button is clicked to perform the heat transfer calculations.

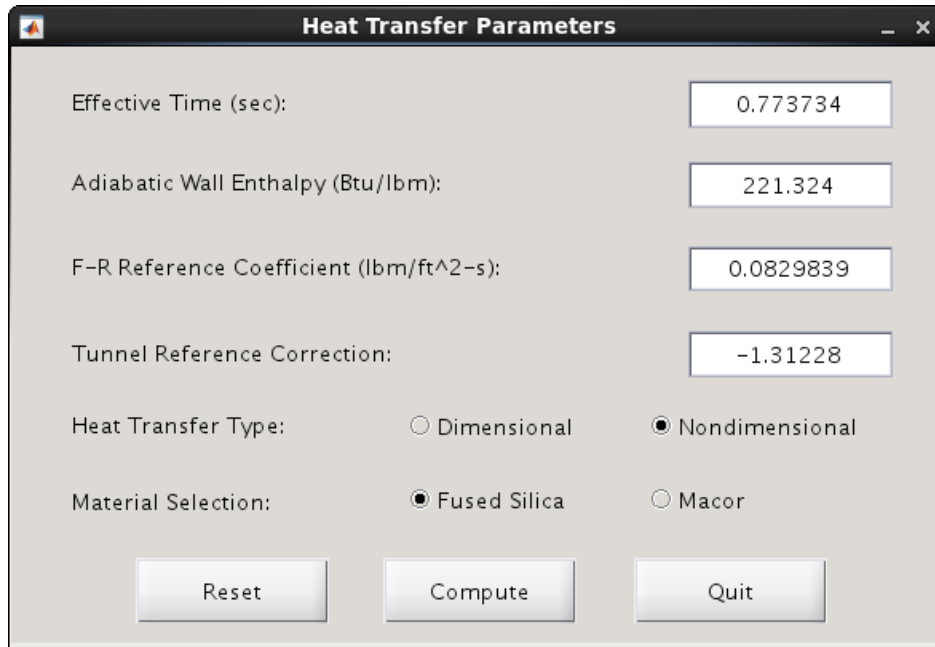


Figure 6: Compute Heat Transfer Tool.

3.2.4. Help Menu:

1. *Checklists*: The lists in figure 7 tell the user how to run a phosphor thermography wind tunnel test. The checklists are displayed in the IHEAT v4.0 terminal window, including sections for the *Load Run*, *Batch*, and *Three-Dimensional (3D) Mapping* capabilities for analyzing the phosphor thermography data.

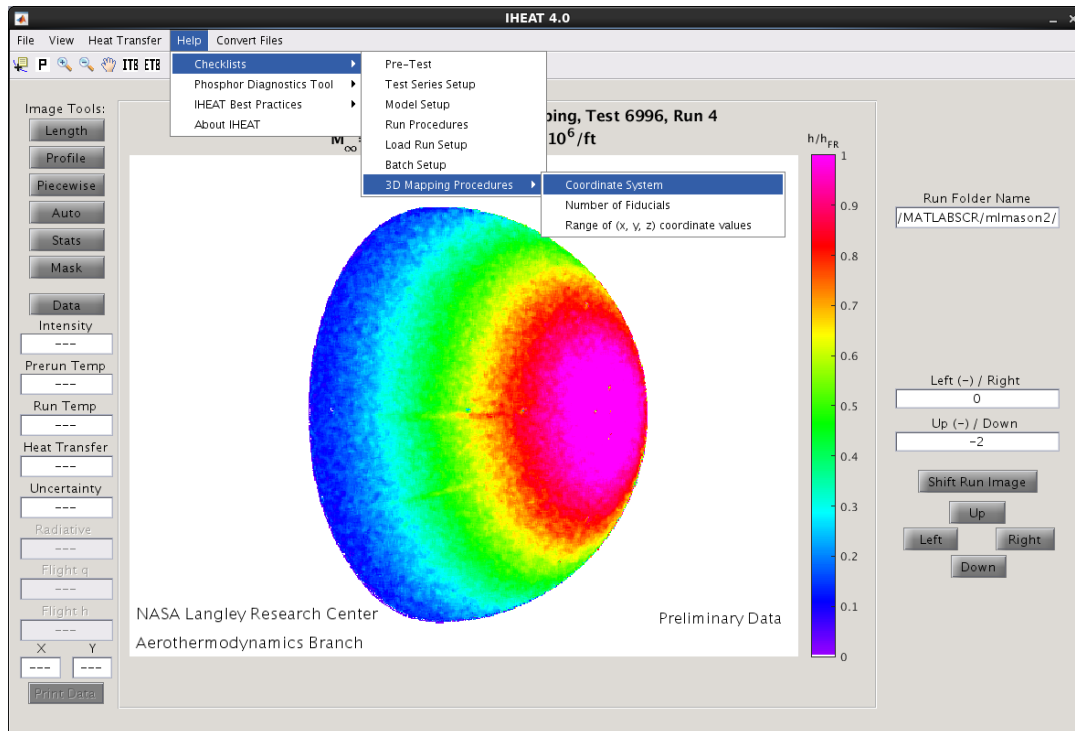


Figure 7: Help Menu, Checklists.

2. *Phosphor Diagnostics Tool*: This tool lists hints for resolving possible phosphor test problems, as shown in figure 8, which are viewed in the IHEAT v4.0 terminal window.

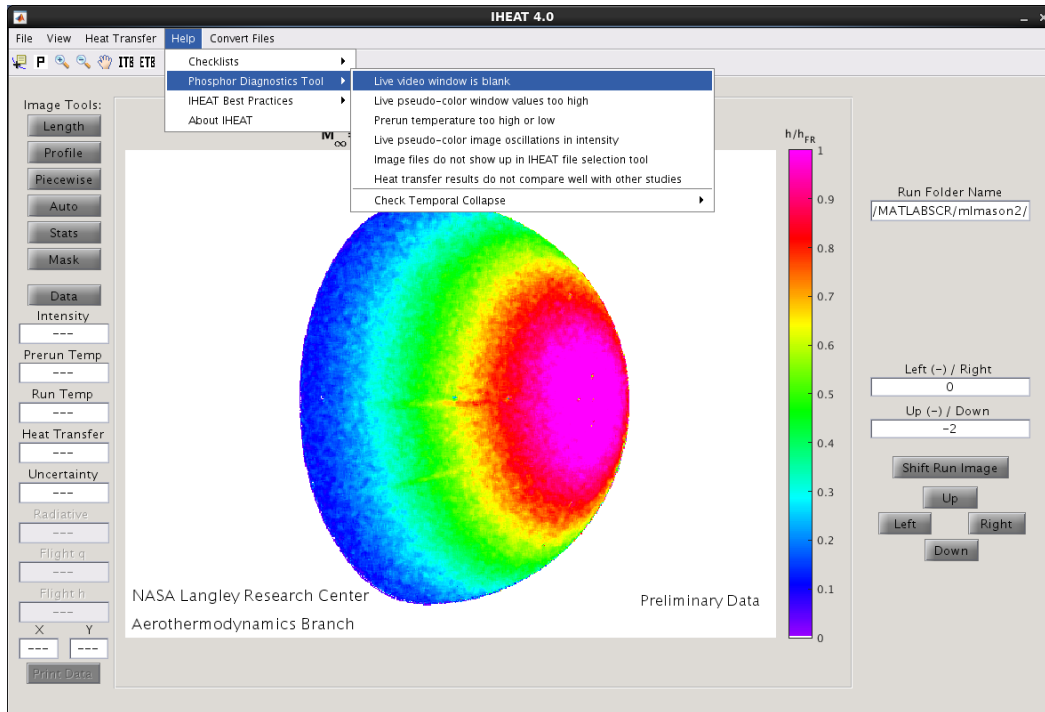


Figure 8: Help Menu, Phosphor Diagnostics Tool.

3. *IHEAT Best Practices*: This section outlines known best practices for a user to follow when running IHEAT v4.0, including solutions if certain errors are encountered while running the software.

3.2.5. Convert Files Menu:

The formats of the phosphor thermography input files were modified from those in IHEAT v3.2 to work in IHEAT v4.0. However, using the *Convert Files* menu, the user has the option to update files formatted for the previous version of IHEAT for use in the newer version of the code. This tool allows the user to reuse existing set-up, flow conditions and position gauge files to reduce phosphor thermography data from earlier tests in IHEAT v4.0. The user must exercise caution when implementing these tools, since the files in the selected directory *will be overwritten* with the reformatted files. Selecting one file of the specified type in a directory is sufficient to change all such files in the same directory (for example, if one **.tekflw** file is selected in a folder, then all the **.tekflw** files in that folder will be converted).

To convert a set-up file, the user must specify the wind tunnel facility in which the run took place (which dictates the tunnel core size and other variables necessary for the data processing), and the location of the **.dat** LUT file that will be used to convert the pixels in the run and prerun images to temperatures. The facility listed in the set-up file is automatically determined and specified in the dialog box in figure 9, although the user can override that specification if the facility is incorrect. To specify the LUT location, the user

clicks the *Find* button and navigates to and selects the **.dat** LUT file. The user clicks *Apply* to complete the conversion of the set-up file.

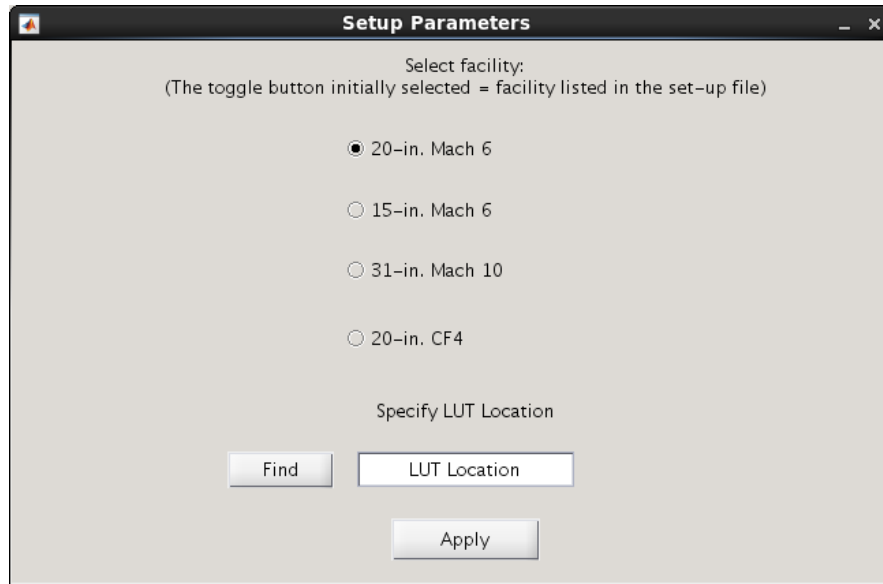


Figure 9. Convert Files Menu, Set-up Parameters.

Note: These conversion tools assume a specific format for each type of input file. If the code cannot successfully interpret and convert a given file with a different initial format, the user may need to manually modify the format of the file to work in IHEAT v4.0.

3.2.6. Toolbar Menu Icons:

Most of the tools in the toolbar menu are built-in functions in the overall scripting language used to compile the software that provide information about the IHEAT v4.0 images, with the exception of the *Insert Text Box* and *Edit Text Box* tools.

1. The first item to the left in the red circle in figure 10 is the data point cursor. After clicking on this tool, the user can click anywhere in the image to obtain data for a given pixel location. As the data point on the hemisphere model in figure 10 shows, this tool lists the x and y pixel location, the color index, and the red, green, and blue indices for the point on the image indicated by a black rectangle. The color index will be the intensity, temperature, heat transfer, or uncertainty value at the pixel indicated on the model, depending on which parameter is displayed in the image.

With the left mouse button, the user can either click on a different pixel location in the image or drag the current data point to a different position to change the location of the current data point. Right clicking on this data point opens another menu, also shown in figure 10, which allows the user to delete data points (called a *datatip* in the built-in menu), create a new data point, or change the style of the tool. Though the option to *Export Cursor Data to Workspace* is visible in this default menu, this option does not work correctly in the stand-alone executable IHEAT v4.0 software, and therefore, should not be used.

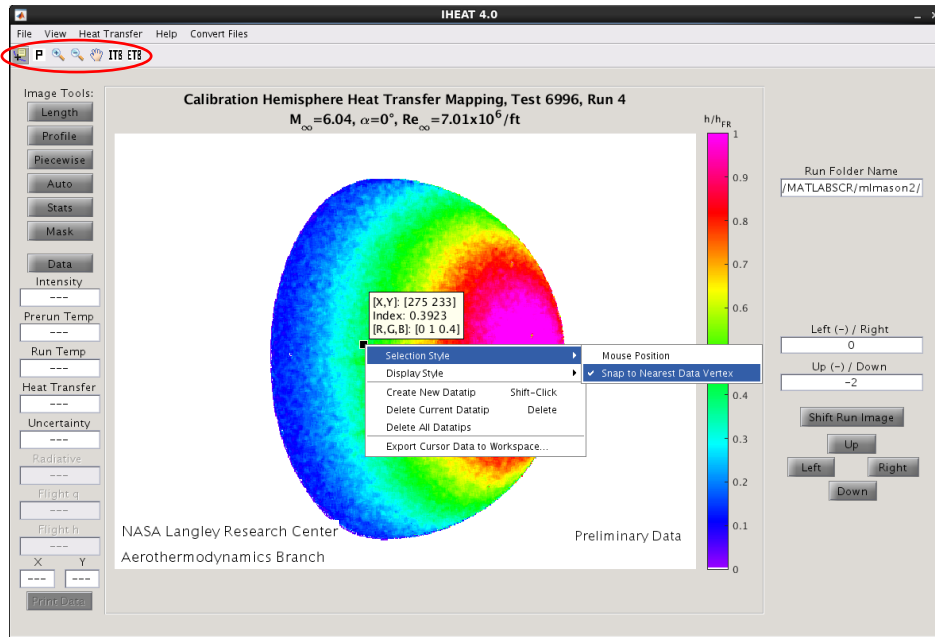


Figure 10: Toolbar Menu, Data Point Cursor.

2. The white icon with a black “P” in the toolbar is the *Pixel Information* tool. When the user clicks on this tool, the pixel information appears in the lower left corner of the user interface, as circled in red in figure 11. As the user moves the cursor over the image, the pixel information is updated. This tool displays data for the current image to two decimal places of accuracy per the default settings of the scripting language in which the software is compiled. In the *Length*, *Profile*, *Piecewise*, *Auto Profile*, *Stats*, and *Mask* tools, the *Pixel Information* tool is activated to show the user the pixel location of the cursor as the lines, points, or rectangles, respectively, are drawn.

3. The next two buttons on the toolbar menu in figure 10 resemble magnifying glasses with either a “plus” or a “minus” sign in the middle. These tools allow the user to zoom in or out from an image, respectively. When the *Zoom In* button is highlighted, the image is magnified by a factor of two each time the user single-clicks on the image with the left mouse button, or rotates the mouse scroll wheel forward one click. Another way to zoom into the image is to drag the mouse (while depressing the left mouse button) over a region of interest on the image. To zoom out, the user can rotate the mouse scroll wheel backward one click or hold the shift key while clicking on the image with the left mouse button. When the user double-clicks on the image, the original view is restored. The user can also right click to see zoom options, as shown in figure 12, such as *Reset to Original View*. If the *Zoom Out* button is selected, the same zoom options are available, except the left-click and shift + left-click options are reversed.

4. The next icon in the toolbar menu in figure 10 allows the user to pan a zoomed image. When the *Pan* tool is selected, the cursor icon changes to a hand when the user scrolls over the image, which resembles the hand enclosed in red in figure 12. The user then can click and drag points on the image with the left mouse button to pan the image. A right click shows a menu with pan options similar to the zoom options described above.

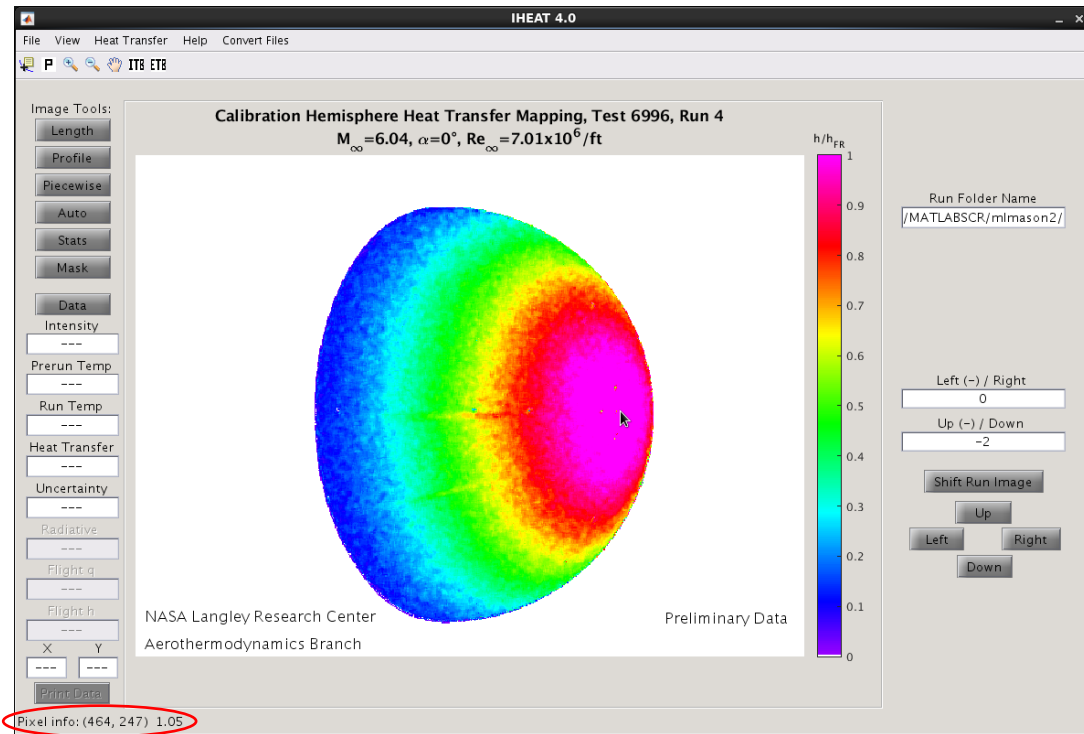


Figure 11: Toolbar Menu, *Pixel Information*.

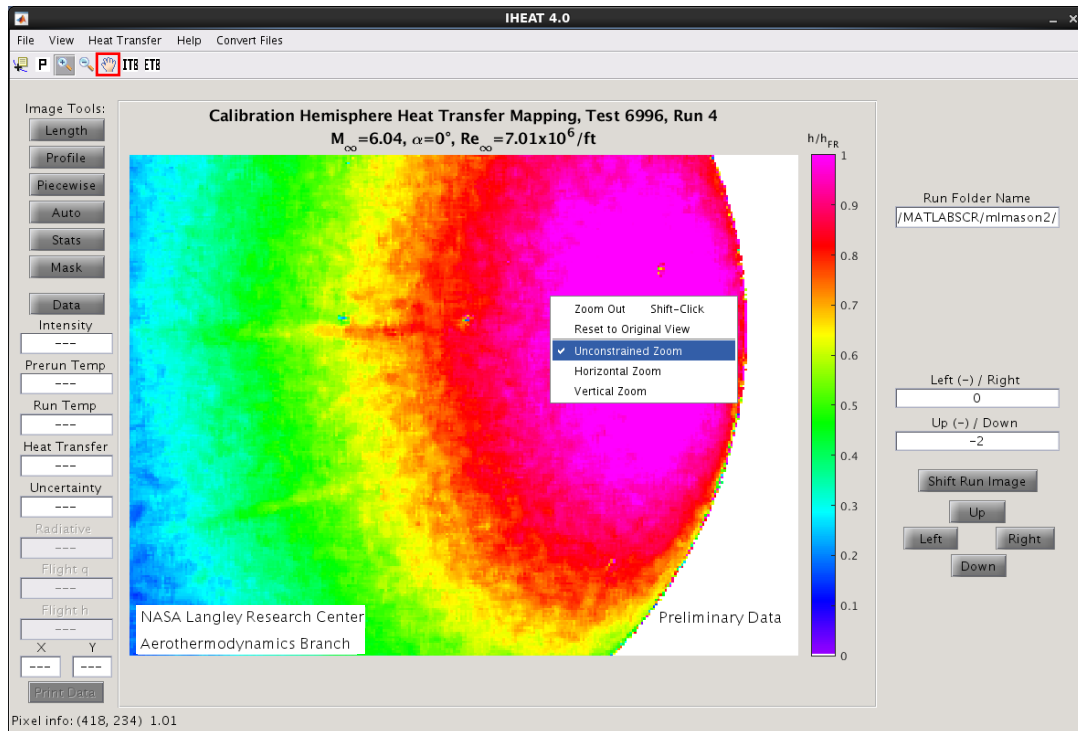


Figure 12: Toolbar Menu, *Zoom and Pan*.

5. The last two icons in the toolbar menu allow the user to either insert or edit a text box to place user-defined labels on the GUI image. These tools therefore have icons labeled

ITB and *ETB* for *Insert Text Box* and *Edit Text Box*, respectively. The user can specify the parameters of the text box as shown in the input dialog for the *ITB* tool in figure 13 and place the text box in the appropriate location on the image as shown in figure 14. The *ETB* tool allows the user to later change the location of the text box, the number of lines of text in the box, and the words in the text box.

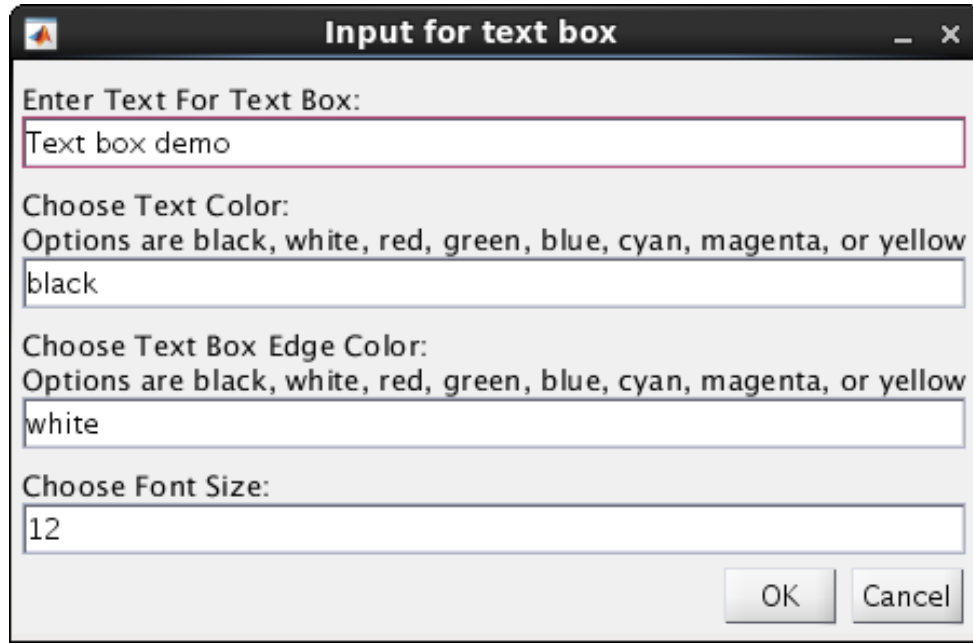


Figure 13: Toolbar Menu, *Insert Text Box (ITB)* Tool, Input Dialog.

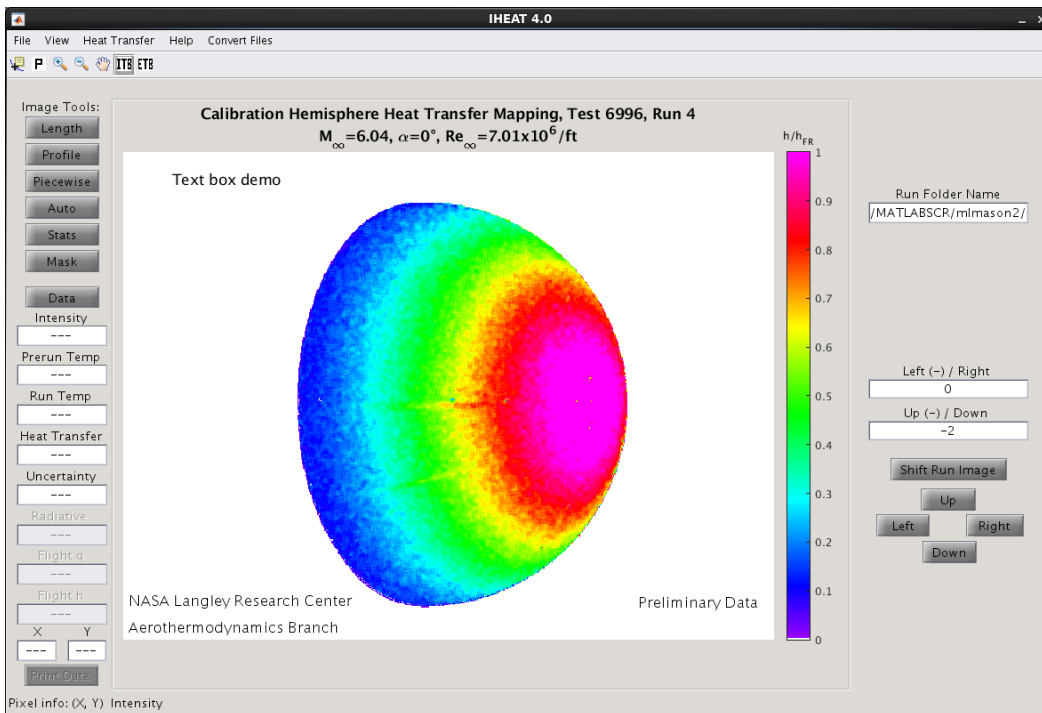


Figure 14: Text Box Inserted using the *ITB* Tool.

3.2.7. Image Tools: (left column on GUI)

1. *Length/Profile*: The same procedure is used to operate both the *Length* and the *Profile* tools, so only the *Length* tool is demonstrated in this tutorial. In figure 15, the *Length* tool is selected, and a blue line is drawn on the image. To draw the line, the user can either click and drag a line on the image (as was done in this case) or type the endpoints of the line into the *Activate Line Cuts Menu* text boxes prior to entering either the *Length* or the *Profile* tool. If the latter option is used, the user must click somewhere in the image after clicking on the button for the line cut tool and before pressing “g” to extract the line cut data. For more information on how to create a line using this method, refer to the *Activate Line Cuts Menu* description in the *File* menu section at the beginning of this tutorial.

When the user manually creates the line by clicking and dragging, the second endpoint of the line is placed when the user releases the left mouse button. The line may not extend beyond the edges of the image; any endpoint placed beyond these boundaries is automatically changed to the closest edge of the image. To change the position of the line manually, the user may left click on either endpoint and drag it to a different position within the image. The *Pixel Information* tool is activated when the *Length* or *Profile* tools are implemented, so the user can select appropriate pixel locations for the endpoints of the line based on the coordinates provided in the lower left corner of the user interface.

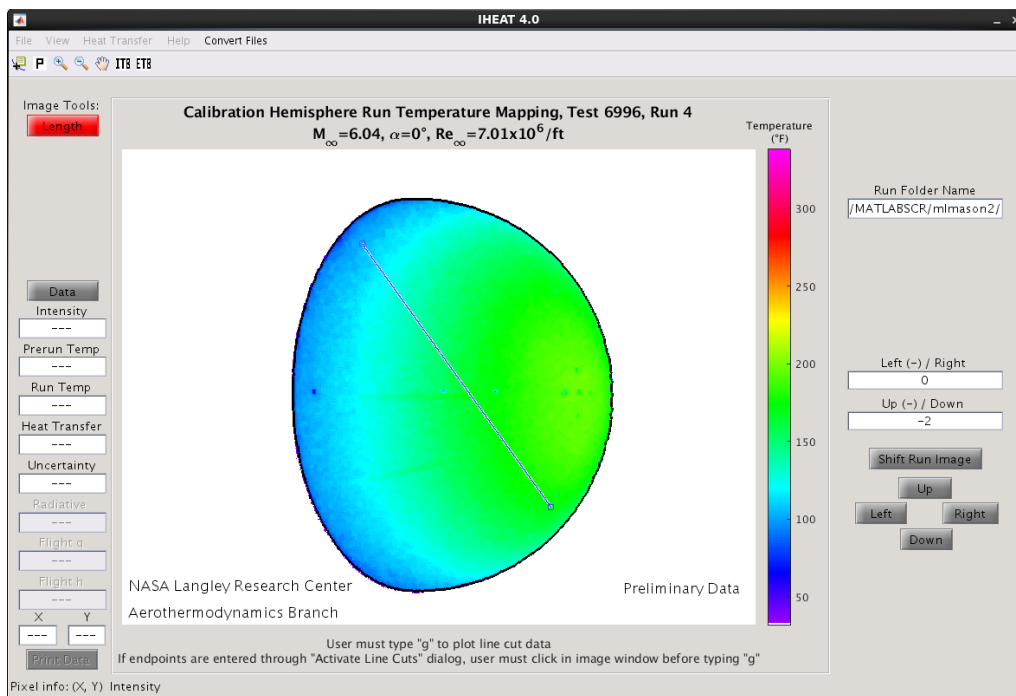


Figure 15: Image Tools, *Length* and *Profile*.

While either the *Length* or the *Profile* tool button is red, the tool is active and more line cuts can be taken. Other image tools are disabled while either the *Profile* or the *Length* tools are active (and thus, the other tools temporarily are not visible on the GUI). The reference dimension used to normalize the x data in a line cut made with the *Profile* tool is

either the length of the most recent line cut taken in the *Length* tool, or the length of the current *Profile* line cut if the *Length* tool has not been used in the IHEAT v4.0 session.

A message below the image in the GUI in figure 15 tells the user to type “g” on the keyboard to plot the line cut data. Figure 16 shows the *Save* dialog and plotted line cut data that appear when “g” is pressed if the run temperature image is visible in the user interface. The *Save* window must be closed before the user can modify the line cut or exit the *Length* or *Profile* tool. The line cut data in the figure can be saved using the *File* menu. The *Edit* menu in the figure allows the user to add a text box to the figure or change the figure title, the axes limits and the axes labels. The other icons in the figure toolbar menu allow the user to view and analyze the line cut data. The *Save* dialog box gives the user the option to save ASCII line cut data in either a *.dat* file or a *.txt* file.

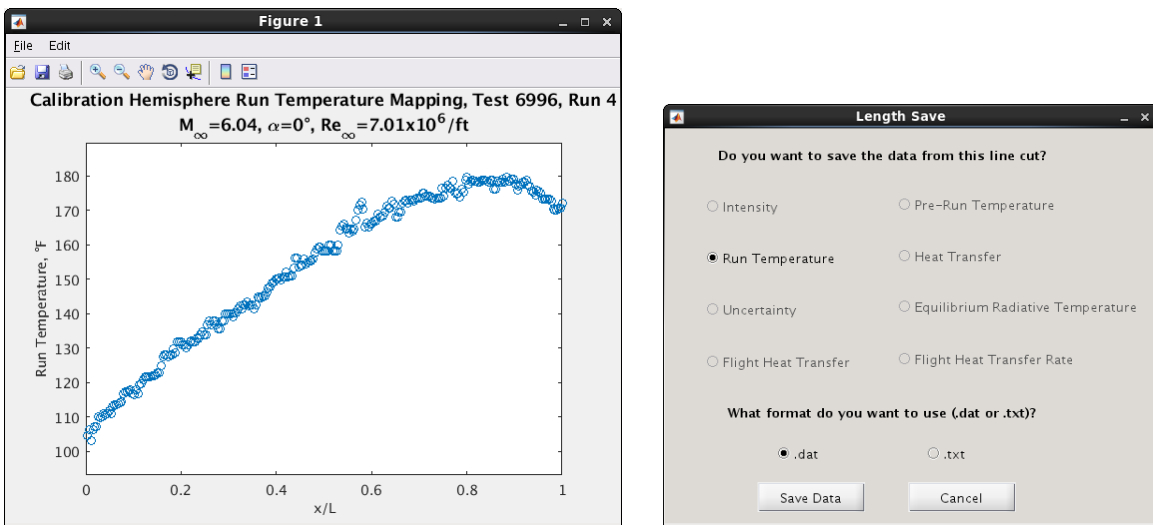


Figure 16: Image Tools, *Length*: Line Cut Data and Save Dialog.

2. *Piecewise*: Another feature of IHEAT v4.0 is the *Piecewise* tool, demonstrated in figure 17. This tool is similar to the *Length* tool, but allows the user to create a segmented line cut. The message below the image tells the user to press “n” to create a new line or “p” to plot the line cut data. When a new line is created, the user can left click on the end of the current line and drag the mouse to another position to define the new line segment. If “n” is not pressed after a line is drawn, clicking and dragging the final endpoint of the most recent line segment will change the position of that line segment on the image. Only the position of the newest line segment can be modified; all of the other line segments remain stationary. If the last line segment is one pixel long, this segment is automatically deleted before the data is plotted. A *Piecewise* line cut can contain any number of line segments.

The heat transfer data in figure 18 is extracted from the *Piecewise* line cut in figure 17 when “p” is pressed. The x/L dimension extends from zero at the first endpoint to one at the last endpoint along the overall segmented line. Once the data has been plotted, the message below the image changes to tell the user to either exit the *Piecewise* tool or press “c” to create a new *Piecewise* line cut. The *Save* dialog box shown in figure 18 must first be closed before a new line cut can be created or the tool can be exited. The user also must

click in the image window before pressing “c” to make the main IHEAT v4.0 GUI the active figure again to enable the *Piecewise* tool to create a new line cut.

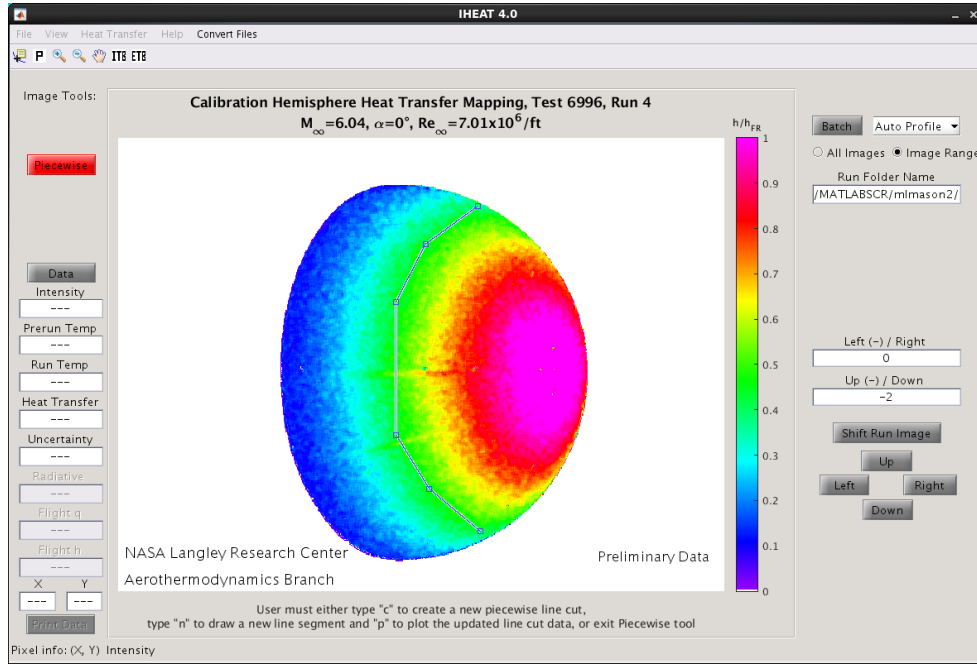


Figure 17: Image Tools, *Piecewise*.

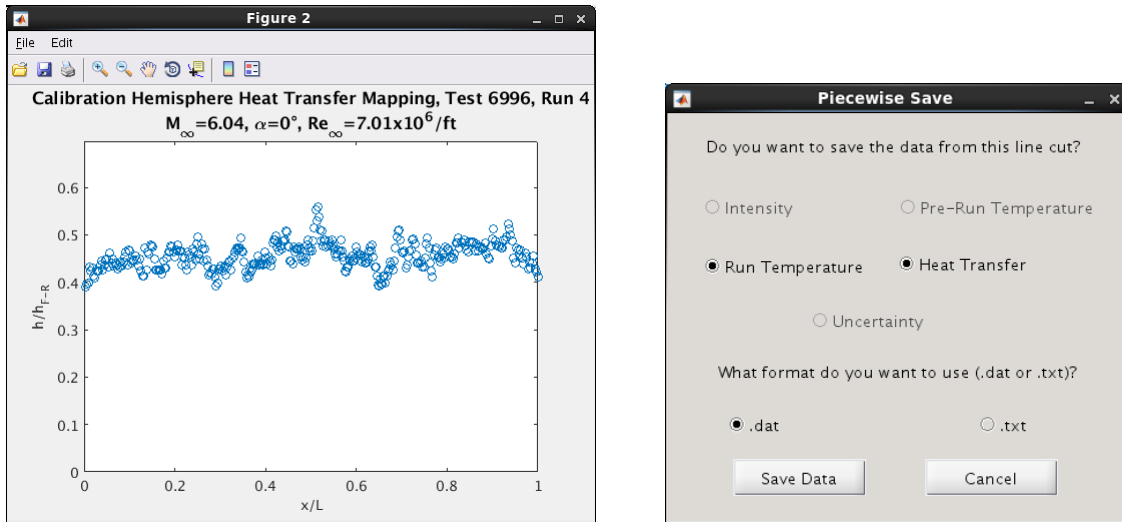


Figure 18: Image Tools, *Piecewise*: Line Cut Data and Save Dialog.

When the user exits the *Piecewise* tool, the location of the most recent *Piecewise* line cut is stored in memory and can be used in the *Batch* tool (described later) to apply the same line cut to every frame in the run folder. If the user reenters the *Piecewise* tool during the same IHEAT v4.0 session, a pop-up message allows the user to load the existing line cut or create a new line cut. If the existing line cut is selected, the user can press “n” to add new line segments to the end of the line. After the user plots the *Piecewise* line cut data, the option to press “c” to clear the existing data and create a new line cut again is available.

3. *Auto Profile*: When the *Auto Profile* tool is first entered, the button that corresponds to the visible image plane is highlighted, and the line cuts extracted from the set-up file are displayed in a tab-delimited list. A different plane is displayed when the corresponding button in figure 19 is clicked. To add a new line cut location, the user can type in the x/L or y/y_{ref} location in the appropriate text box, leaving at least one space between the values. The line cuts do not have to be entered in order numerically, because these lists will be rearranged automatically. The user can enter a maximum of 25 axial and 25 longitudinal line cuts.

The *Auto Profile Image* button saves a snapshot of the image, the title and the color bar shown in the middle box of the IHEAT v4.0 user interface as a **.jpeg** file. This button can be used at any time while the *Auto Profile* tool is in use.

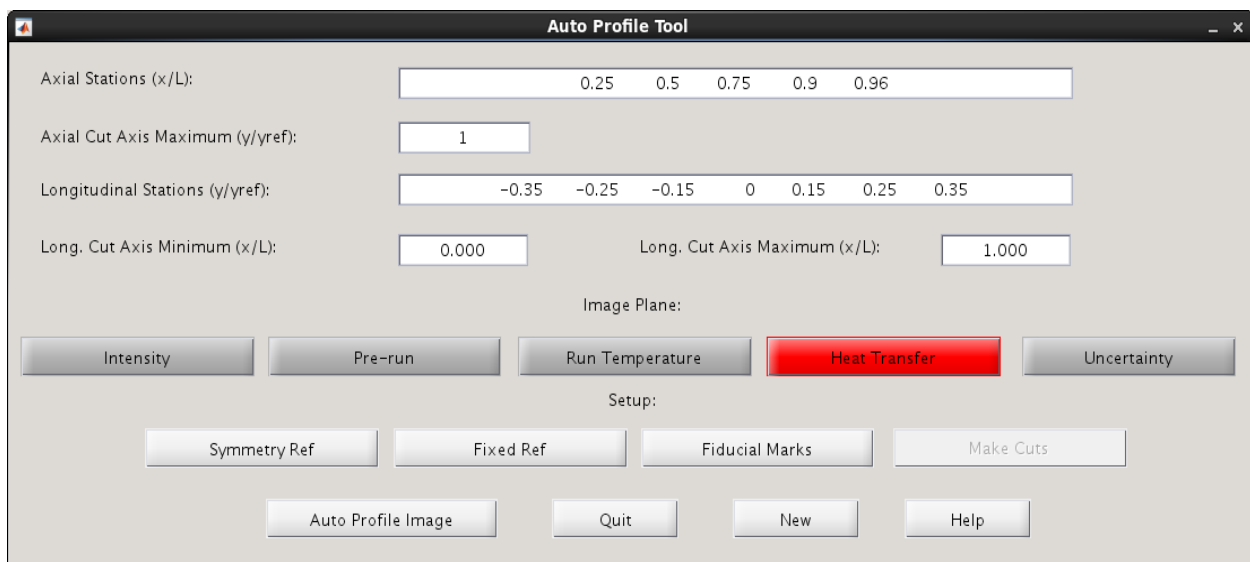


Figure 19: Image Tools, *Auto Profile*.

As figure 19 shows, the *Auto Profile* tool in IHEAT v4.0 requires the user to select the *Fixed Ref* or *Symmetry Ref* option to begin an *Auto Profile* analysis. The *Make Cuts* option is disabled until the reference line and fiducial marks are placed on the image as shown in figure 20. The first time the *Auto Profile* tool is entered for a run and either the *Fixed Ref* or the *Symmetry Ref* button is pressed, the user must enter at least two x and two y values in fiducial marks before closing *Auto Profile*.

After the required fiducial marks are entered, additional points are created individually according to the user's needs. An error message appears when the user repeats a previous x or y fiducial mark value, and the new fiducial mark is removed. To change the location of a fiducial mark with a given value, the previous point with the same value first must be deleted. When the user clicks on or near an existing fiducial mark, the choice to either keep or delete the mark is presented. Deleted fiducials are displayed on a list and disappear from the image after the *Refresh* button is clicked or when *Auto Profile* is closed and reentered.

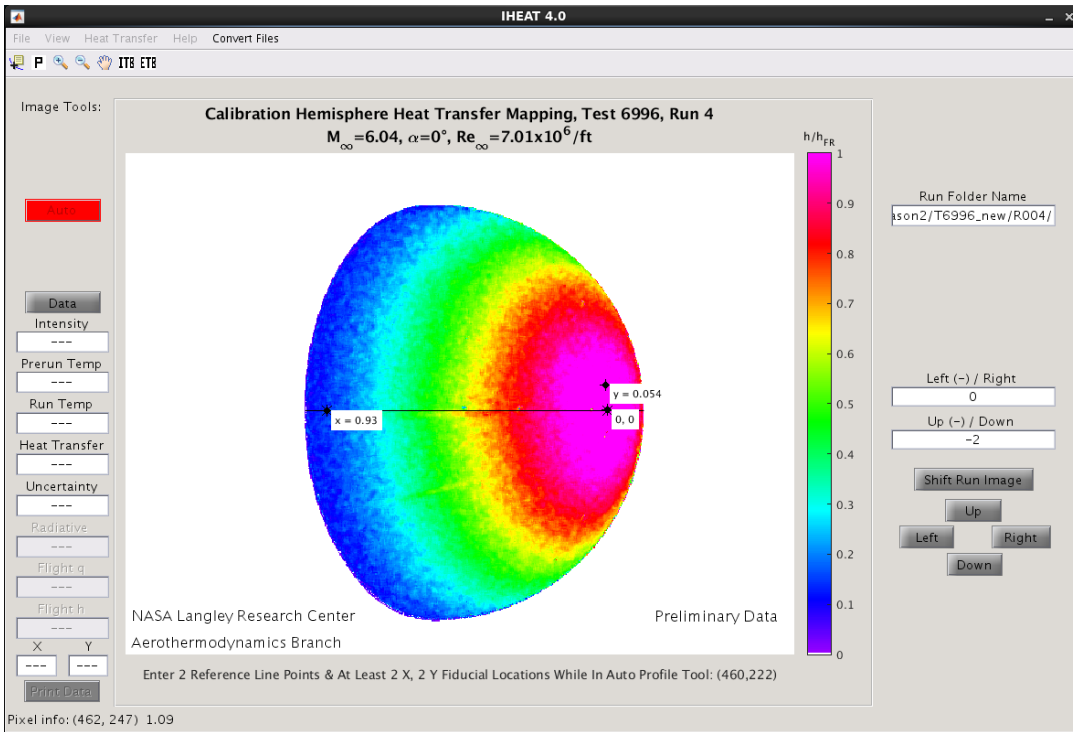


Figure 20: Image Tools, *Auto Profile*: Reference Line and Fiducial Marks.

As figure 20 shows, the fiducial mark values are labeled in IHEAT v4.0. The user can either enter one or both of the nondimensional values for a given fiducial mark, which correspond to x (or x/L) and y (or y/y_{ref}). Examples of the labels in each case are shown in the figure. If the *Auto Profile* tool is later reentered, these labels are again visible. *View > Refresh* can be used to hide any marks or lines that are still visible after the *Auto Profile* tool is exited.

4. The *Make Cuts* dialog box has several options for viewing and saving line cuts from an *Auto Profile* analysis (see figure 21).
 - A. When the *Select All Lines Cuts* item is toggled on, the axial, longitudinal and reference line cuts are toggled on; when this item is deselected, all of the line cuts are toggled off. The line cuts also can be toggled on or off individually.
 - B. *Show All Line Cuts* toggles all the line cuts on and opens figures with the line cut data. If this option is deselected, open figures with line cut data (as well as any other open figures created during the data reduction process, excluding the IHEAT v4.0 main and sub-GUIs) are closed using a “close all” command.
 - C. Two options exist to save line cut data from the *Auto Profile* analysis, including a combined data file with all of the line cuts, in appropriate folders within the current directory listed in the *Run Folder* text box.
 1. *Save All* allows the user to save all the line cut data from the *Auto Profile* analysis.
 2. To exclude line cuts during a *Save* operation, the user can select the specific line cuts to be saved and click *Save*.
 - D. *Quit* allows the user to exit the *Make Cuts* tool without saving any of the *Auto Profile* line cuts.

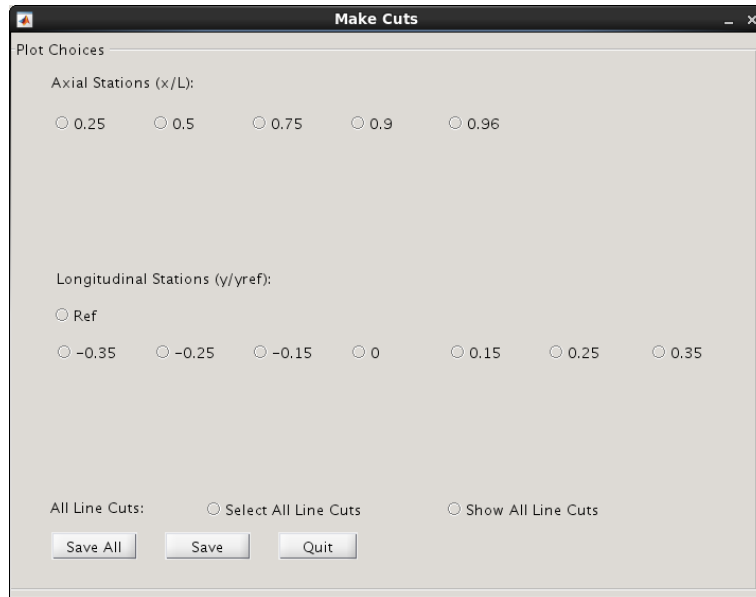


Figure 21: Image Tools, *Auto Profile: Make Cuts.*

5. *Stats*: The *Stats* tool in IHEAT v4.0, shown in figure 22, provides information about a rectangular region of interest (ROI) on the image. After selecting this tool, the user must left-click on the image and drag the mouse to generate the rectangular ROI, releasing the left mouse button when the ROI is correct. This procedure yields a histogram and a set of statistics for the ROI, as shown in figure 23. These statistics are provided: the number of points in the ROI, the maximum value, the minimum value (greater than zero), the mean value, and the standard deviation of the ROI data. The ROI cannot be modified in this tool, so the *Stats* tool must be closed and reentered to evaluate a different ROI in the image.

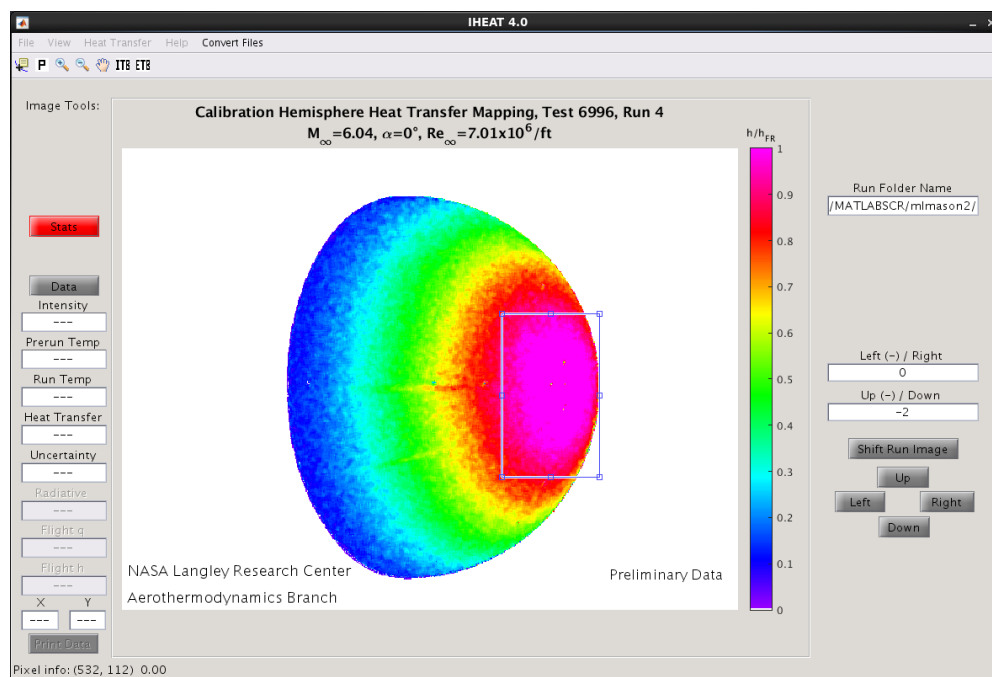


Figure 22: Image Tools, *Stats.*

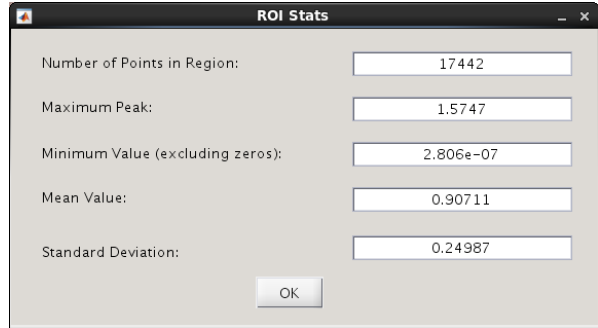
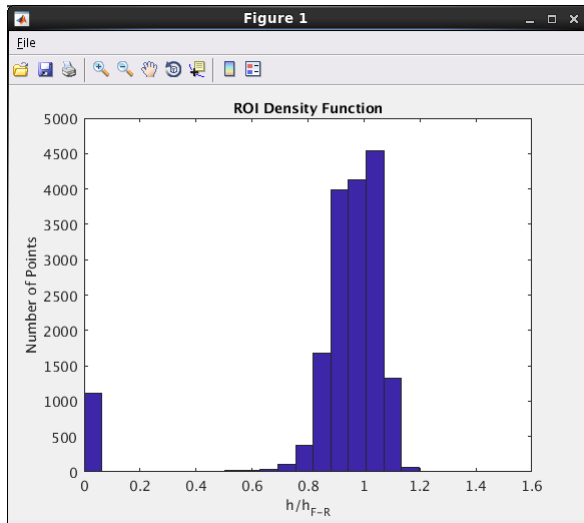


Figure 23: Image Tools, Stats: Histogram and ROI Data.

6. *Mask*: Figure 24 shows the *Mask* tool used to hide an ROI on the image, and figure 25 shows the same image after the masked ROI is hidden (by exiting the *Mask* tool, which calls the *Refresh* function). The user can mask multiple regions of the image at a time by dragging the corners of the *Mask* rectangle to different locations on the image. All of the pixels within the rectangle are masked, so the user should not position the rectangle over any useful data in this process. All of the masked regions are hidden from view by setting the data for those pixels equal to zero. *View > Undo All Mask Edits* restores the original images and data (refer to the description of *Undo All Mask Edits* in the *View* menu section). When the *Batch* tool is used, any regions that have been hidden in the example run image using the *Mask* tool also will be masked in the *Batch* data files.

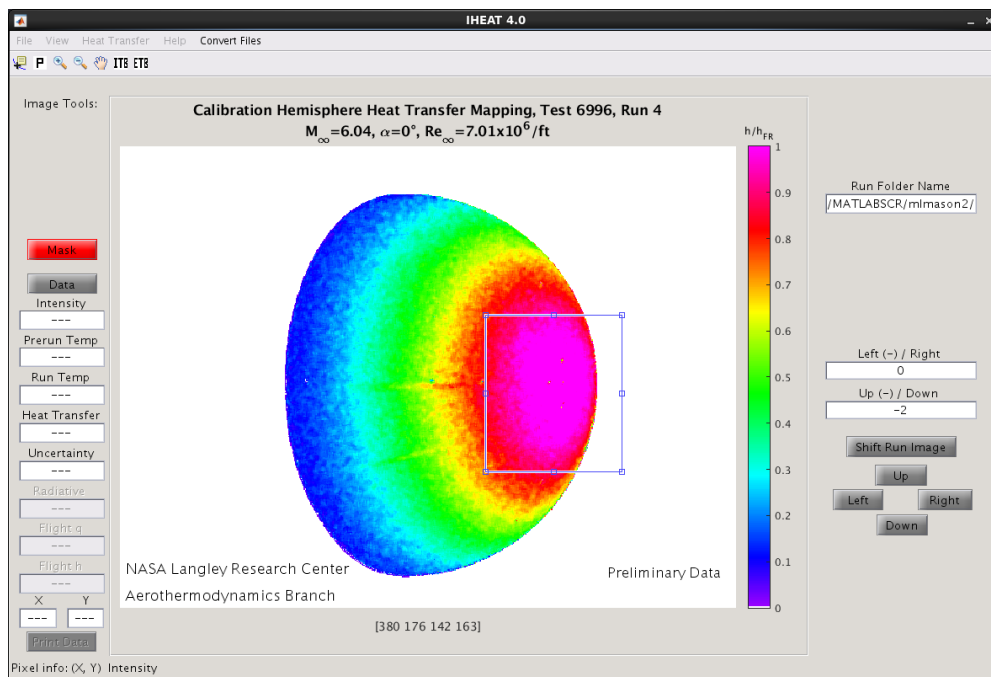


Figure 24: Image Tools, Mask.

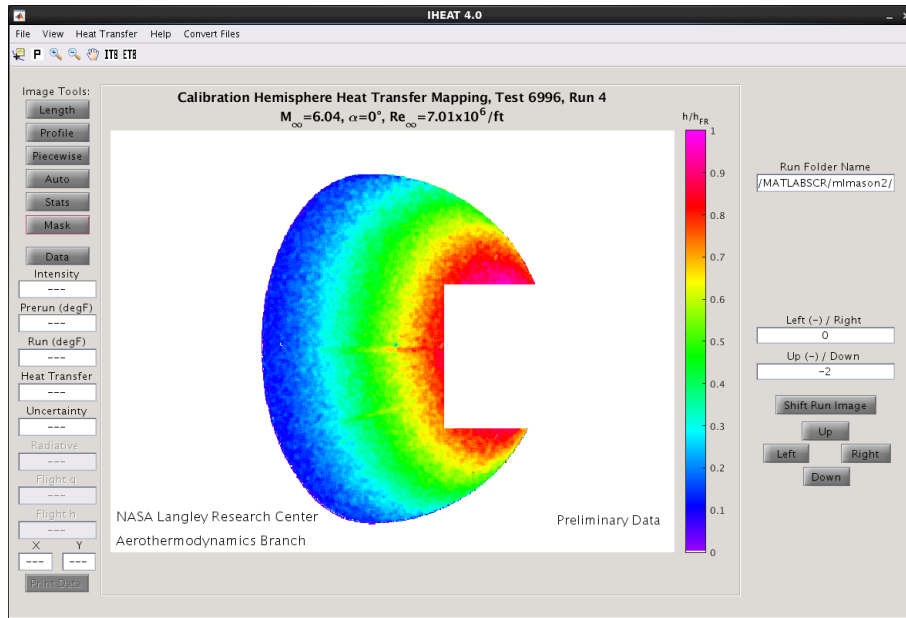


Figure 25: Image Tools, *Mask: Refresh* Applied.

7. *Data/Print Data* Tools: The combined *Data* and *Print Data* tools are shown in figure 26. When *Data* is clicked, a black point appears in the upper left corner of the image and the *Print Data* button is enabled. All of the data that are available at the specified pixel location (for images up to, and including, the visible image) are listed in the appropriate text boxes under the *Data* button. Since the heat transfer image is shown in figure 26, the first four text boxes contain information. The *Intensity* text box refers to the data from the green pre-run intensity image plane. The user can either drag the point to a different pixel location on the image, or type the new pixel coordinates directly into the text boxes labeled X and Y.

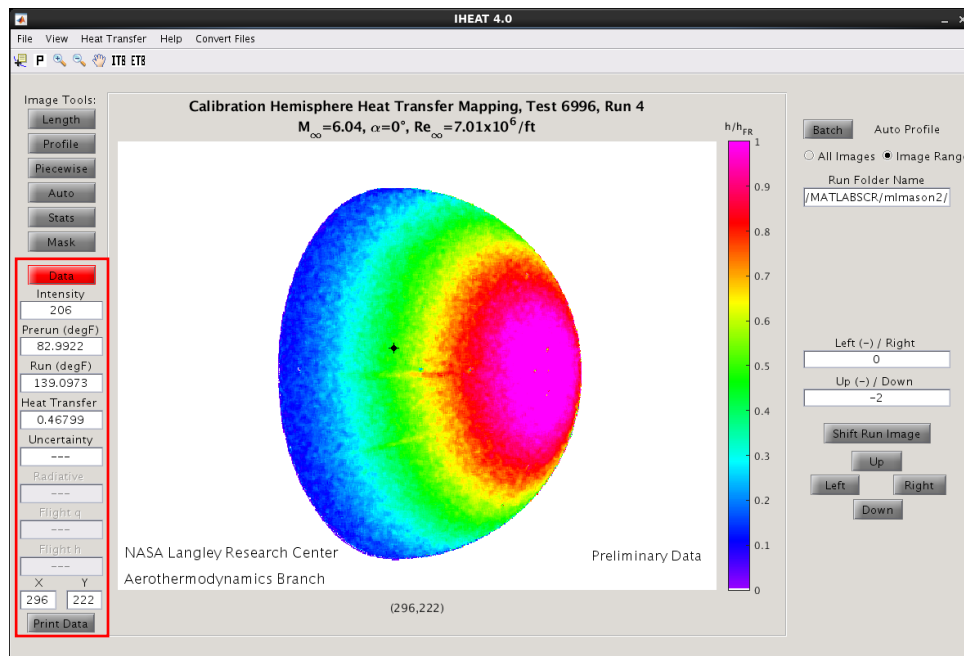


Figure 26: Image Tools, *Data* and *Print Data*.

The *Print Data* button in figure 26 allows the user to save the information about the current data point to a *.txt* file. Once the *Data* tool is exited, the *Print Data* button is disabled and the strings in the text boxes are replaced with the default “---” strings. The *Data* tool can be useful in determining which pixels to select in line cuts or an *Auto Profile* analysis.

3.2.8. Image Tools: (right column on GUI)

The available menus, text boxes and buttons in the right column of the main IHEAT v4.0 GUI change depending on the tools that the user accesses. These tools (excluding the *Activate Line Cuts Menu* option explained in the *File* menu section) are described below.

1. *Batch*: Prior to a *Batch* operation, the user either must create a *Piecewise* line cut or perform an *Auto Profile* analysis and select *Make Cuts* to generate a grid of line cuts for at least one frame in the run folder. This line cut (for *Piecewise*) or grid of line cuts (for *Auto Profile*) is applied to all of the run images in the *Run Folder* during a *Batch* operation. The user can update the name of the run folder in the manner described in the *Load Run* description in the *File* menu section above.

The user has the option to calculate either dimensional heat transfer coefficients or non-dimensional heat transfer coefficients divided by the Fay-Riddell reference coefficient. In the *Batch* operation, the type of heat transfer coefficients calculated for each frame in the run folder matches the dimensionality of the coefficients calculated in the initial analysis. For a *Batch* operation that uses an *Auto Profile* grid, the *Batch* function also produces a combined data file that includes the $y/y_{ref} = 0$ line cut from each of the reduced frames in a semicolon delimited file that can be read into external software to perform a check of the temporal collapse of the data. If the $y/y_{ref} = 0$ line cut is not included in the initial *Auto Profile* analysis, this file lists the reference line cuts instead. When the *Batch* button is selected, messages are displayed in the IHEAT v4.0 terminal window (as shown in figure 27 for an *Auto Profile* grid) as each individual image is saved.

```

Terminal
File Edit View Search Terminal Help
Loading Preliminary Files for Auto Profile Batch...
Set-Up File Loaded
Position Gauge File Loaded
Prerun Temperature Image Loaded
Array of Run Temperature Images Loaded
Computing Heat Transfer Images...

Data From Green Prerun Intensity Auto Profile Line Cuts Has Been Saved!

Data From Prerun Temperature Auto Profile Line Cuts Has Been Saved!

Data From Run Temperature Auto Profile Line Cuts, For Image Number 1 of 31,
Has Been Saved!

Data From Heat Transfer Auto Profile Line Cuts, For Image Number 1 of 31,
Has Been Saved!

A .mat File Named /MATLABSCR/mlmason2/T6996_new/R004/t6996r4Batch_mat_files.9/t6996r4f50 Has
Been Saved!

Data From Run Temperature Auto Profile Line Cuts, For Image Number 2 of 31,
Has Been Saved!

Data From Heat Transfer Auto Profile Line Cuts, For Image Number 2 of 31,
Has Been Saved!

A .mat File Named /MATLABSCR/mlmason2/T6996_new/R004/t6996r4Batch_mat_files.9/t6996r4f51 Has
Been Saved!

```

Figure 27: Image Tools, *Batch*: Output Messages.

When the *Batch* operation finishes, the first image in the heat transfer drop-down menu is displayed, as in figure 28. This menu and the frame menu are added to the GUI to allow the user to view the run temperature and heat transfer images in the run folder. The *Auto Profile* and *Mask* tools are disabled after the *Batch* operation. All of the run frames are saved automatically during the *Batch* operation. The user can modify any frame and save the updated data to a new output file using *Save > Data*. The user also can open a saved data file to perform a new *Auto Profile* analysis or use the *Mask* tool on an individual basis.

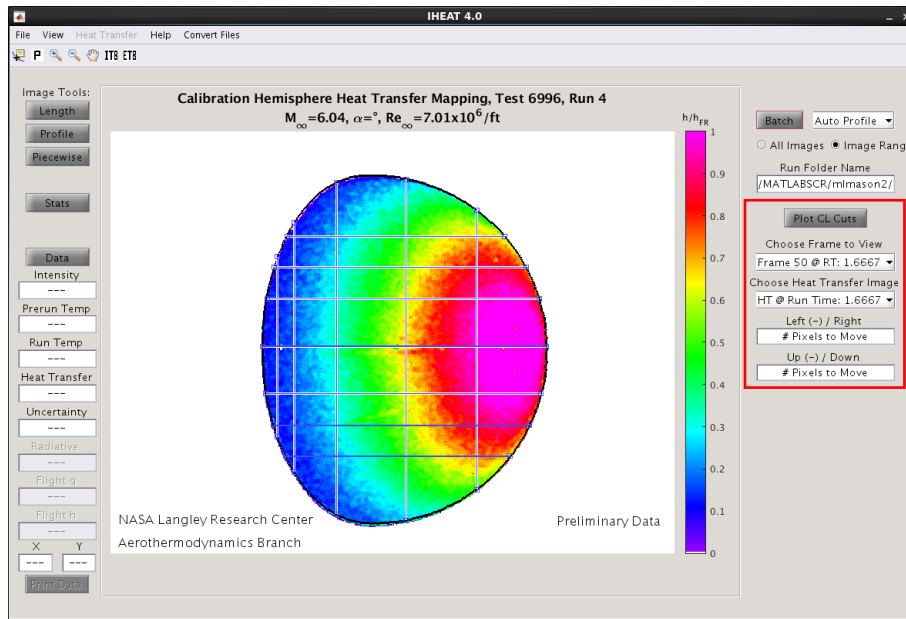


Figure 28: Image Tools, *Batch*: User Interface with Drop-Down Menus.

As the plots in figure 29 show, for *Batch* operations using an *Auto Profile* grid, a separate figure appears that shows the temporal collapse of the $y/y_{ref} = 0$ line cuts (or the reference line cuts if the $y/y_{ref} = 0$ line cut does not exist) for the computed heat transfer images from the run folder. If the user closes this figure and then needs to examine the line cuts again, clicking on the *Plot CL Cuts* button during the same IHEAT session will redraw the figure. For *Batch* operations that use a *Piecewise* line cut, a plot is displayed that compares the *Piecewise* line cut data for every frame. In both cases, the legend initially is positioned outside of the upper right corner of the plot (as shown in the left image in the figure), but the user can select and drag the legend to an appropriate position within the plot as desired (as in the right plot).

The user can specify which frames to include in a copy of the temporal collapse figure by selecting the *Temporal Collapse Range* item in the *Edit* menu. The range of frames can be continuous or specified in intervals. For example, if images numbered 50 to 95 were recorded in a run, the continuous range 11:20 would include frames 60 through 69 (as displayed in the left plot), while the incremented range 1:5:46 would include every fifth frame between 50 and 95 (as shown in the right plot in the figure). If a large number of frames are included in the original figure, the user can enter a frame number in the region of interest to learn the position of that frame in the list prior to specifying the range of line cuts to include in the new figure.

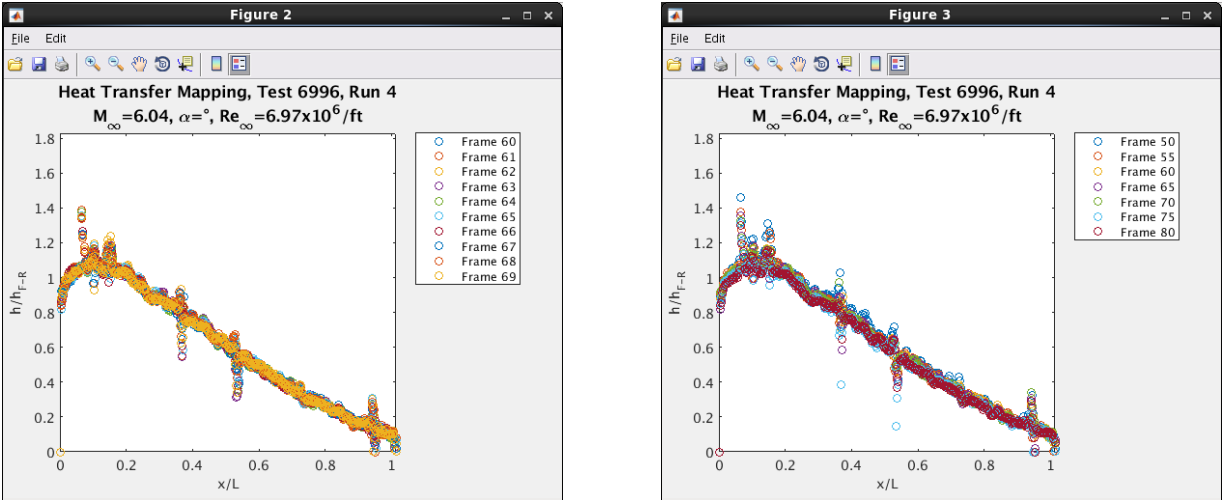


Figure 29. Image Tools, *Batch: Temporal Collapse Plot.*

For any *Batch* operation, the user should select *File > New Batch* prior to clicking the *Batch* button to clear space in the memory for the required variables for *Batch* operations.

2. *Shift Run Image*: The run temperature image can be shifted to align the image with the pre-run temperature image, using the black outline of the prerun image as a guide. Figure 30 shows the run temperature image shifted in the opposite direction. The user can either type the number of pixels to shift the run temperature image directly into the text boxes, or use the up, down, left, and right buttons (shown in the red box in figure 30) to shift the image one pixel at a time. The values in the text boxes indicate the full number of pixels the image has been shifted; thus, if the user enters “0” in both text boxes, the run temperature image returns to the original position, negating all the shifting operations.

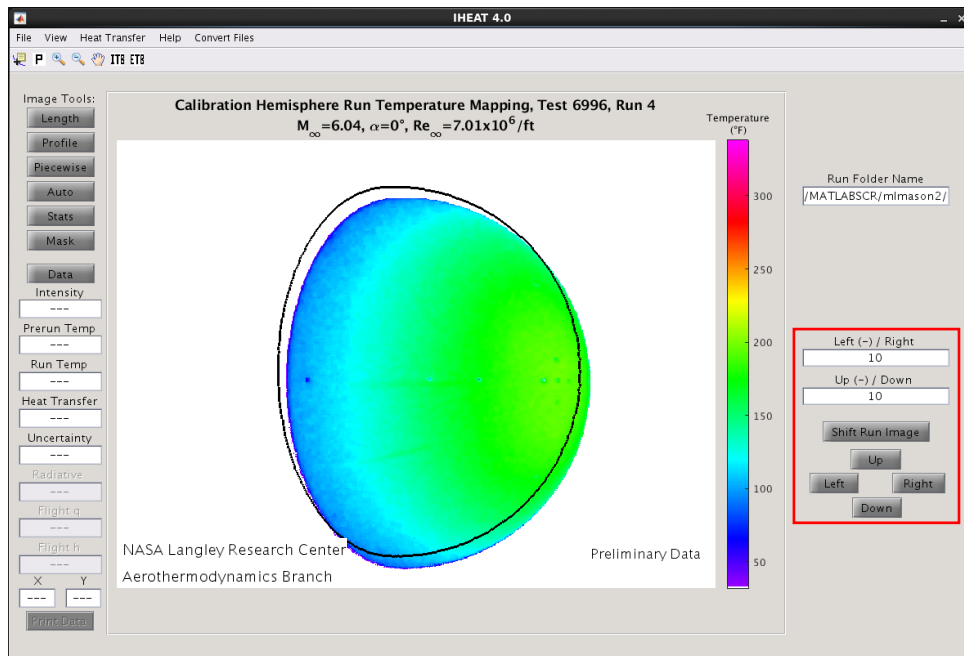


Figure 30: Image Tools, *Shift Run Temperature Image.*

3.2.9. Helpful Hints:

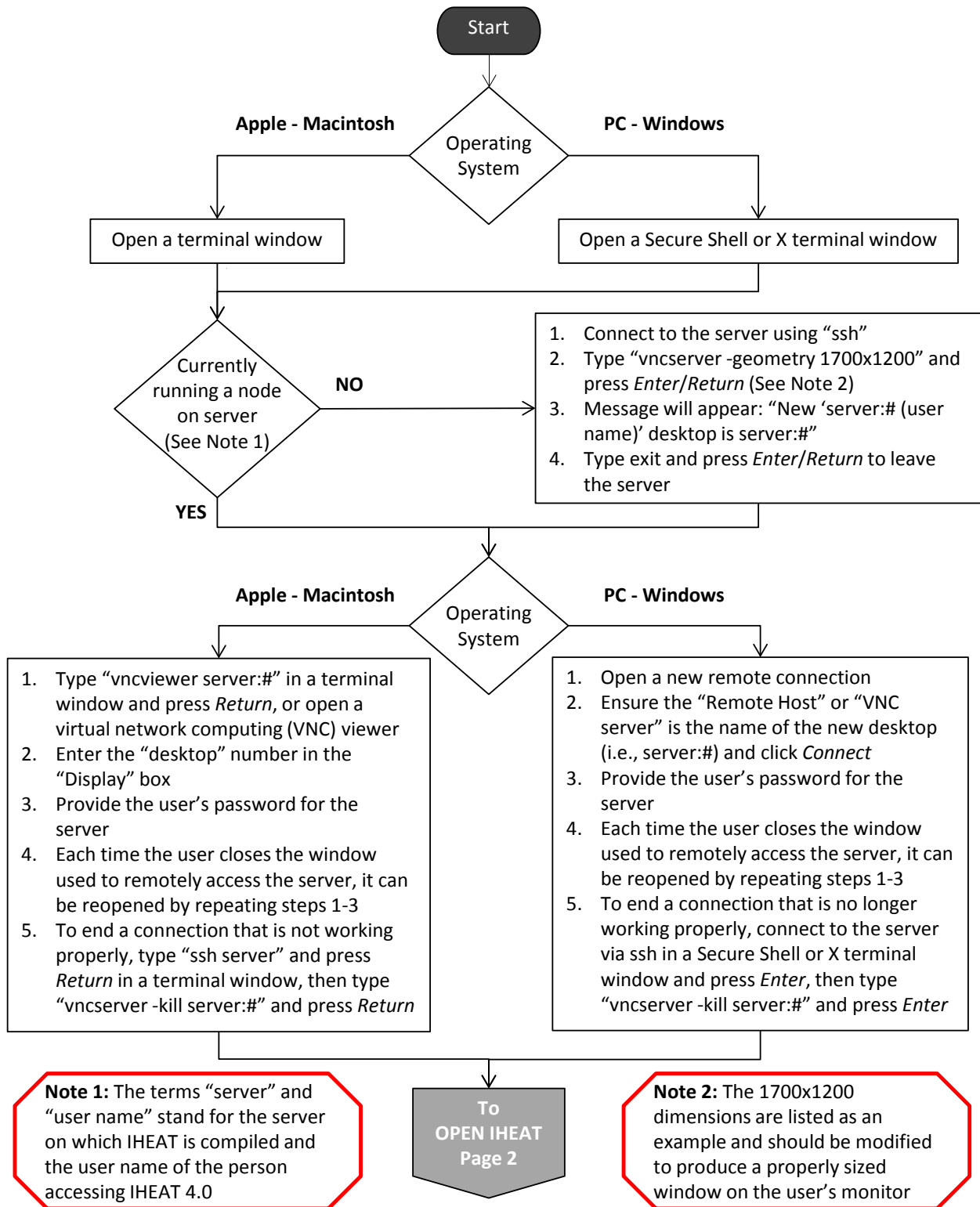
1. Many GUIs are set up to accept “Esc” for *Cancel* or “Enter/Return” for *OK*, particularly:
 - A. *New Test*
 - B. *New Run*
 - C. *New Batch*
 - D. *Save*
 - E. *Exit*
 - F. *Color Bar Range* (which also accepts the letter “A” as a shortcut for *Apply*)
 - G. *Heat Transfer Parameters* (where “Esc” is used for *Quit*, “Enter/Return” for *Compute*)
 - * Note: These shortcuts require the correct window to be active, and will not work if the user is typing in a text box, even in the correct GUI.

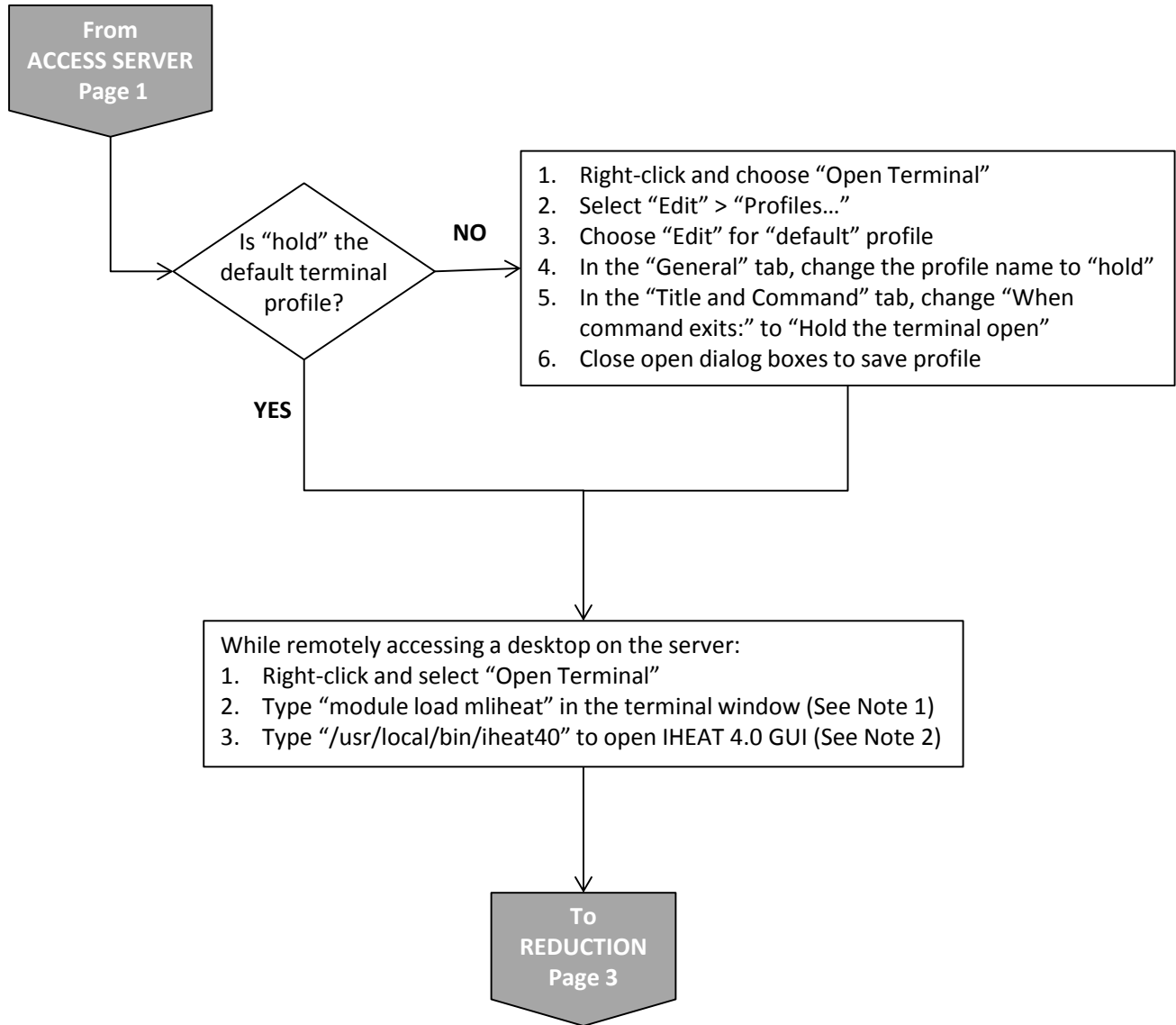
2. If the user clicks on the icon in the upper left corner of each GUI, several options appear that allow the user to control the position of the GUI. For example, the user can choose to keep the GUI in front of all other windows on the current workspace, to move the GUI to another workspace, or to keep the GUI on the current workspace. These features are especially helpful when the user starts up IHEAT on one workspace and switches to another workspace to complete other tasks while IHEAT runs.

3.3. IHEAT v4.0 Flow Chart

ACCESS SERVER

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST





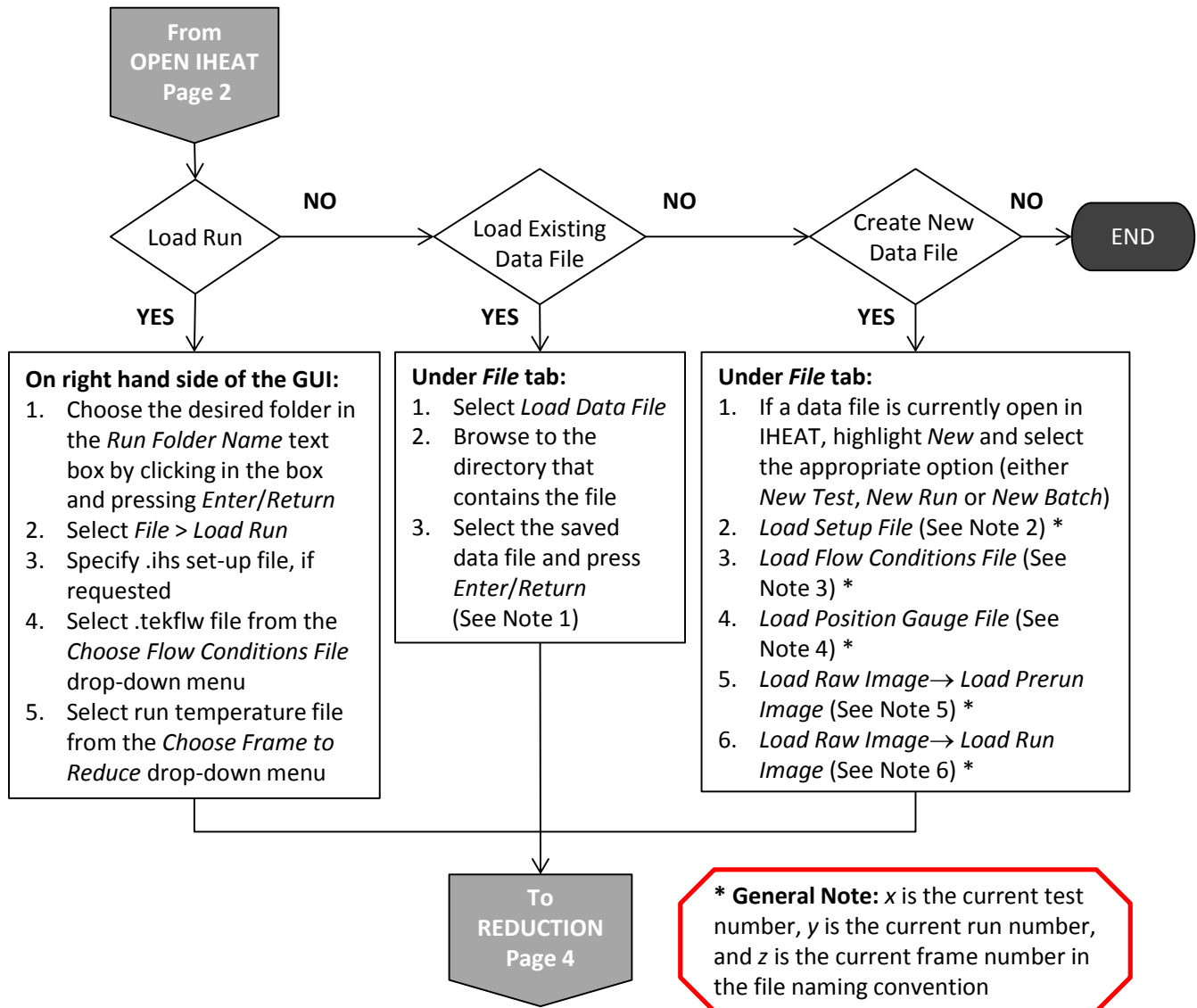
Note 1: Each time a new terminal window is opened to run IHEAT, the command "module load mliheat" must be repeated prior to the first time IHEAT 4.0 is called

Note 2: If IHEAT 4.0 does not open, try typing "chmod +x iheat40" in the terminal window and press *Enter/Return*

General Note: If user navigates to the run directory prior to opening the IHEAT 4.0 GUI, the run folder for that session will automatically be set to the specified run folder, but this step is not required

REDUCTION

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



*** General Note:** x is the current test number, y is the current run number, and z is the current frame number in the file naming convention

Note 1: Ensure the user has read/write access to the files in the directory containing the data to be reduced

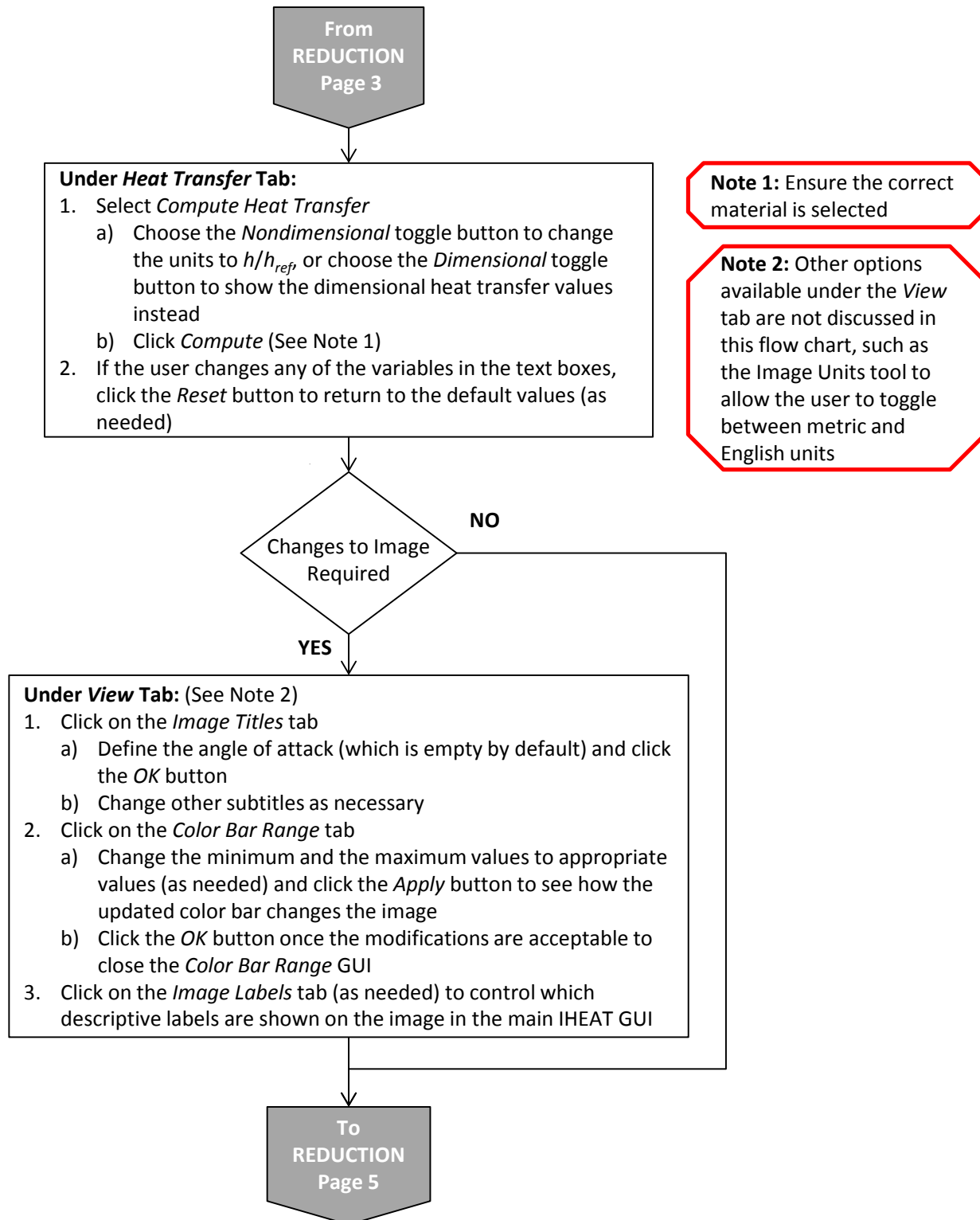
Note 2: cd to the test directory and select the "Tx.ihs" file, unless the setup file is still in memory from a previous run

Note 3: Change the filter to "All Files" and click on "xytn.tekflw" file where n is the correct flow conditions timed file

Note 4: If this file is not still in memory from a previous run, click on the "xy?.tektxt" file (where the ? is a file descriptor that changes per test) and verify the effective time is correct

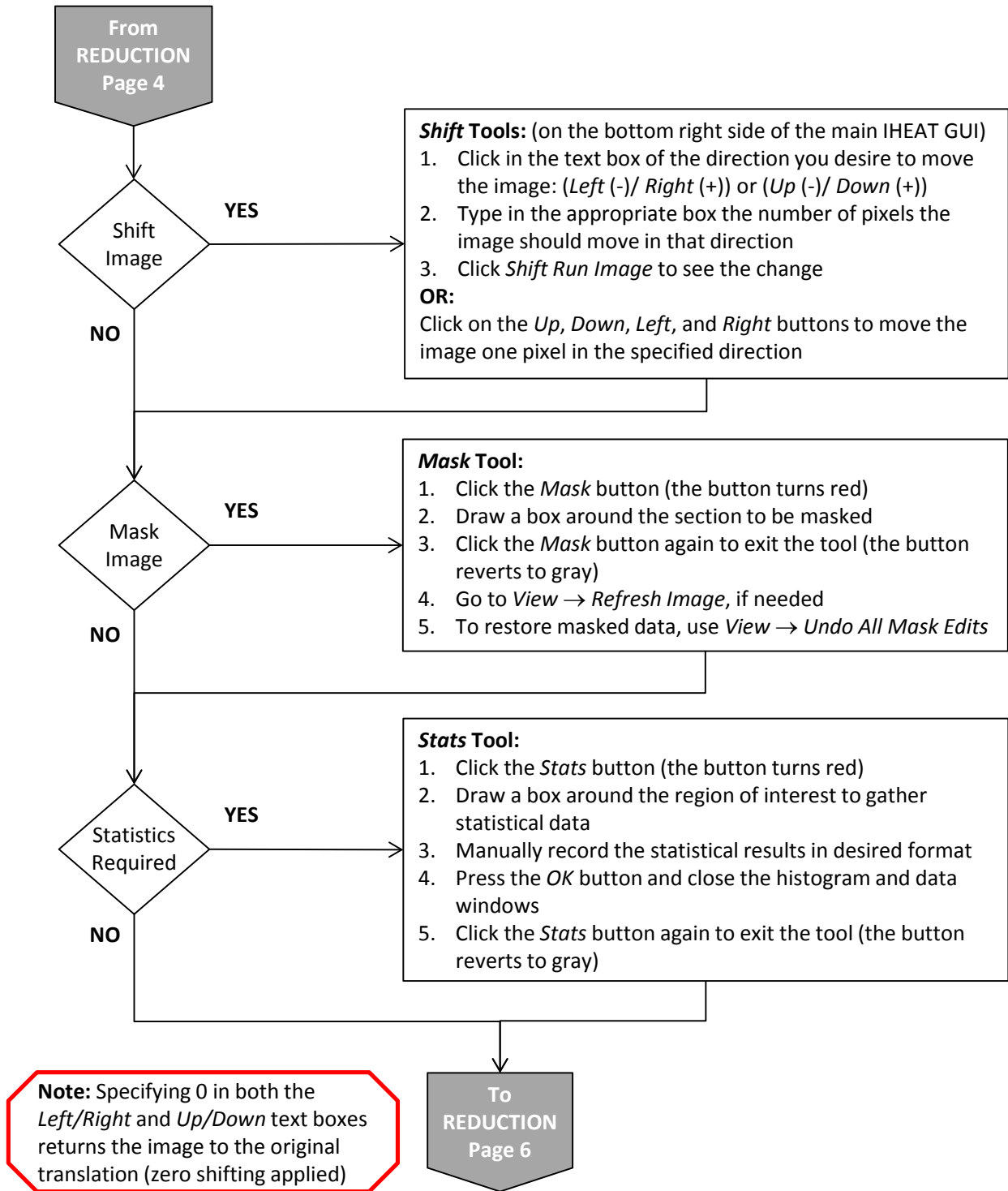
Note 5: Ensure the temperatures in the Prerun image (named "txryPrerun.tif") are uniformly similar to the initial test section temperature between about 70°F and 80°F

Note 6: Check for run image shifting (in the "txry_f_z.tif" file) and, if necessary, shift the run image using the text boxes and the Shift Run Image button or the shift direction buttons in the GUI



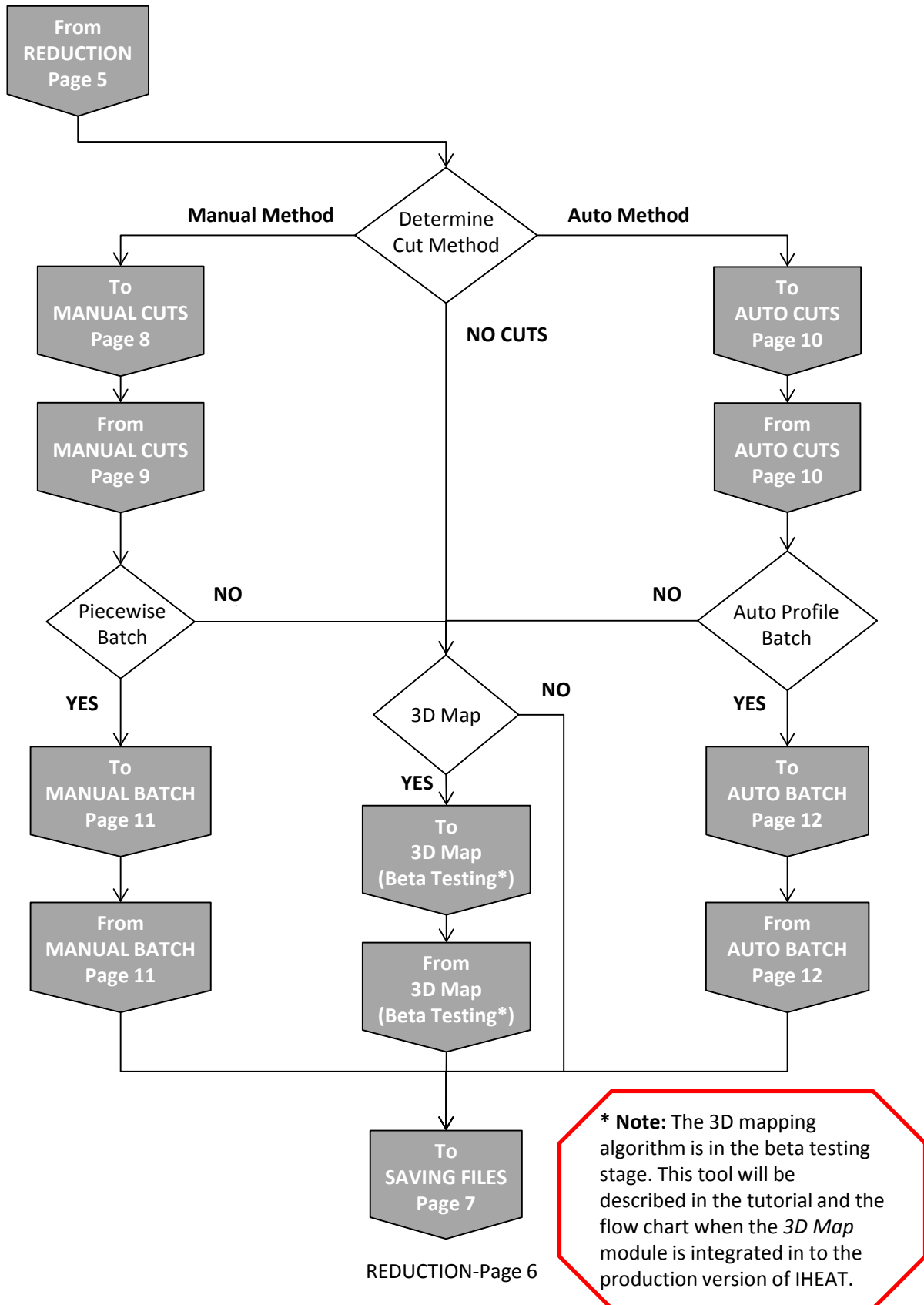
REDUCTION

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



REDUCTION

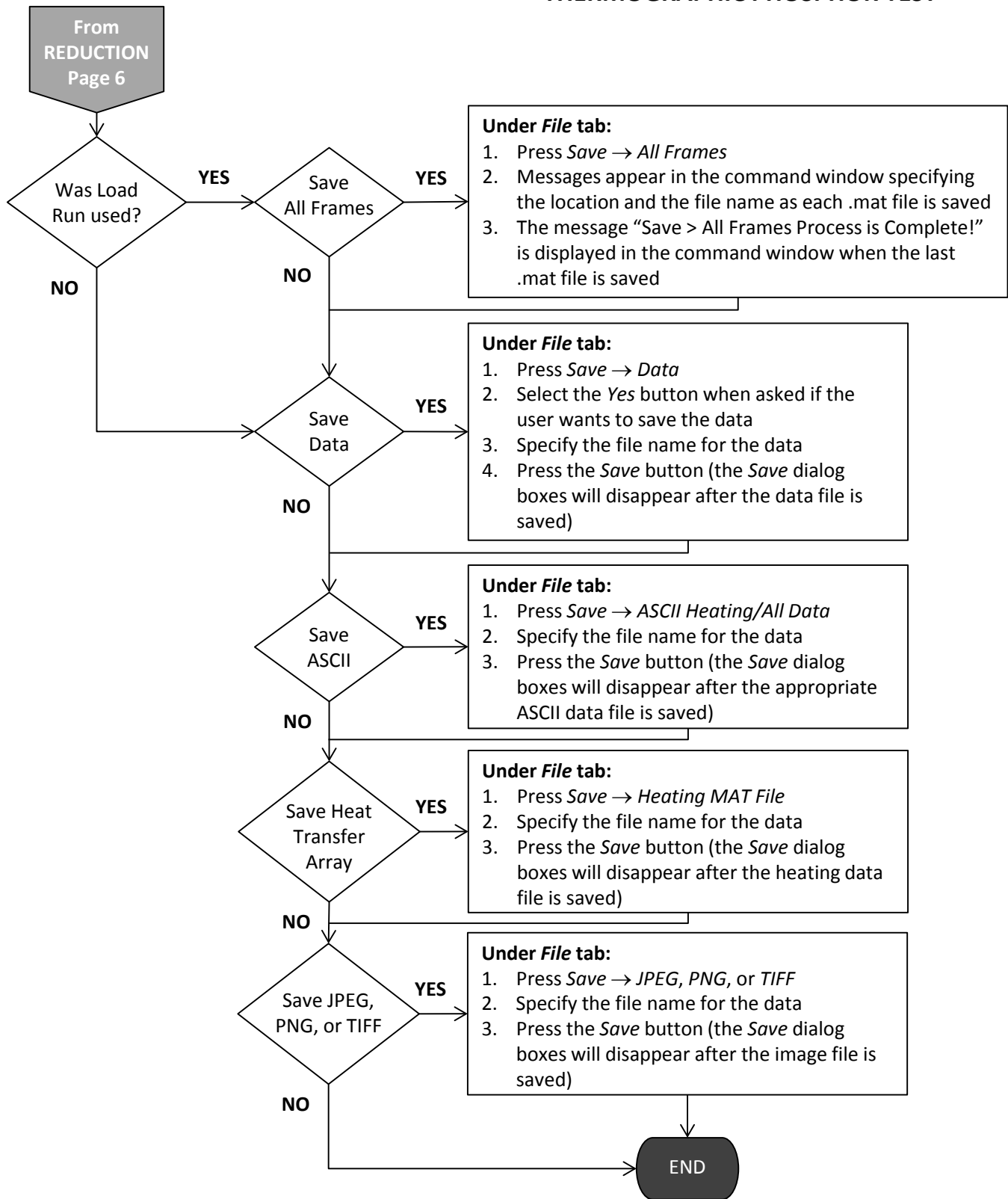
PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



REDUCTION-Page 6

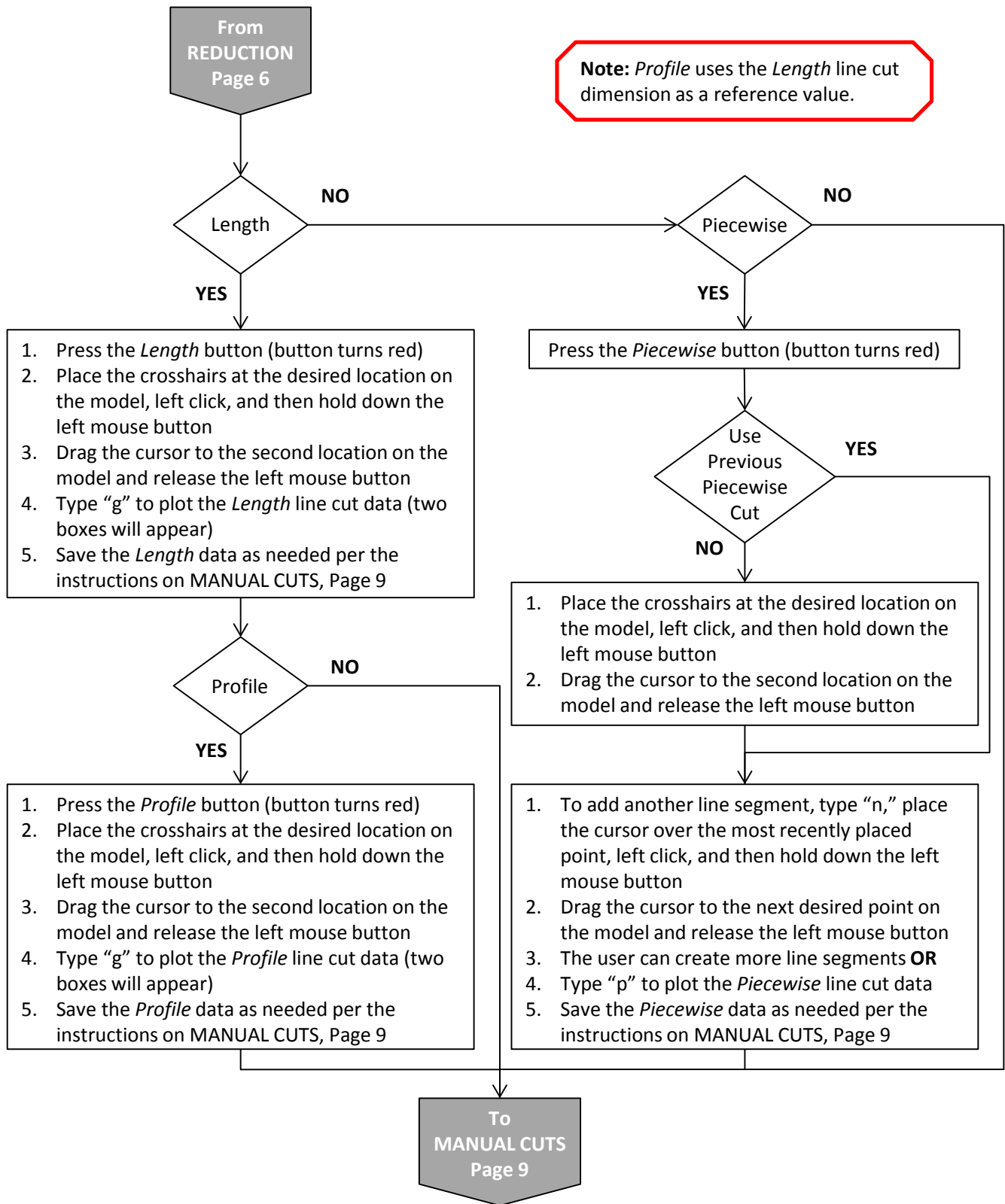
SAVING FILES

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



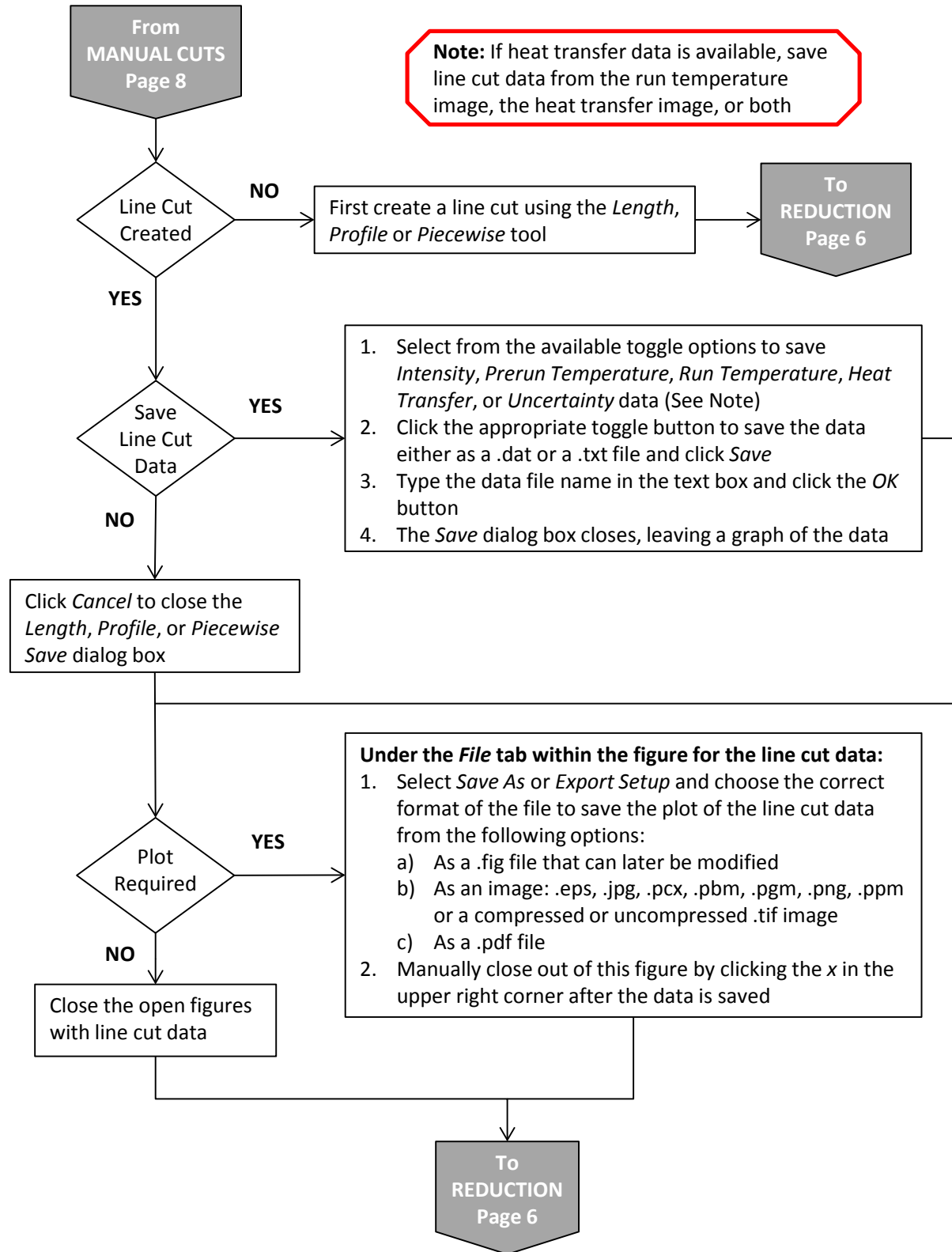
MANUAL CUTS

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



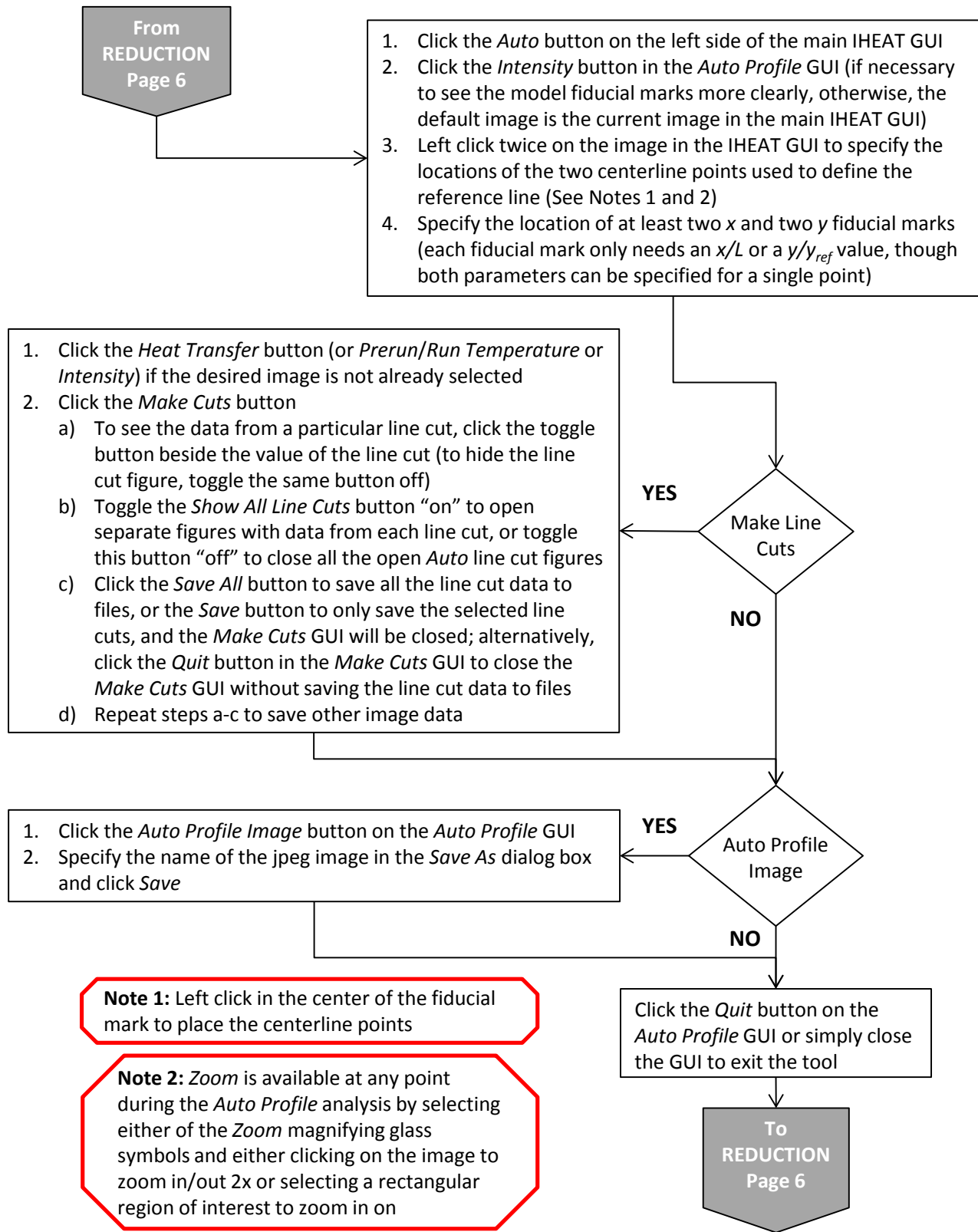
MANUAL CUTS

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



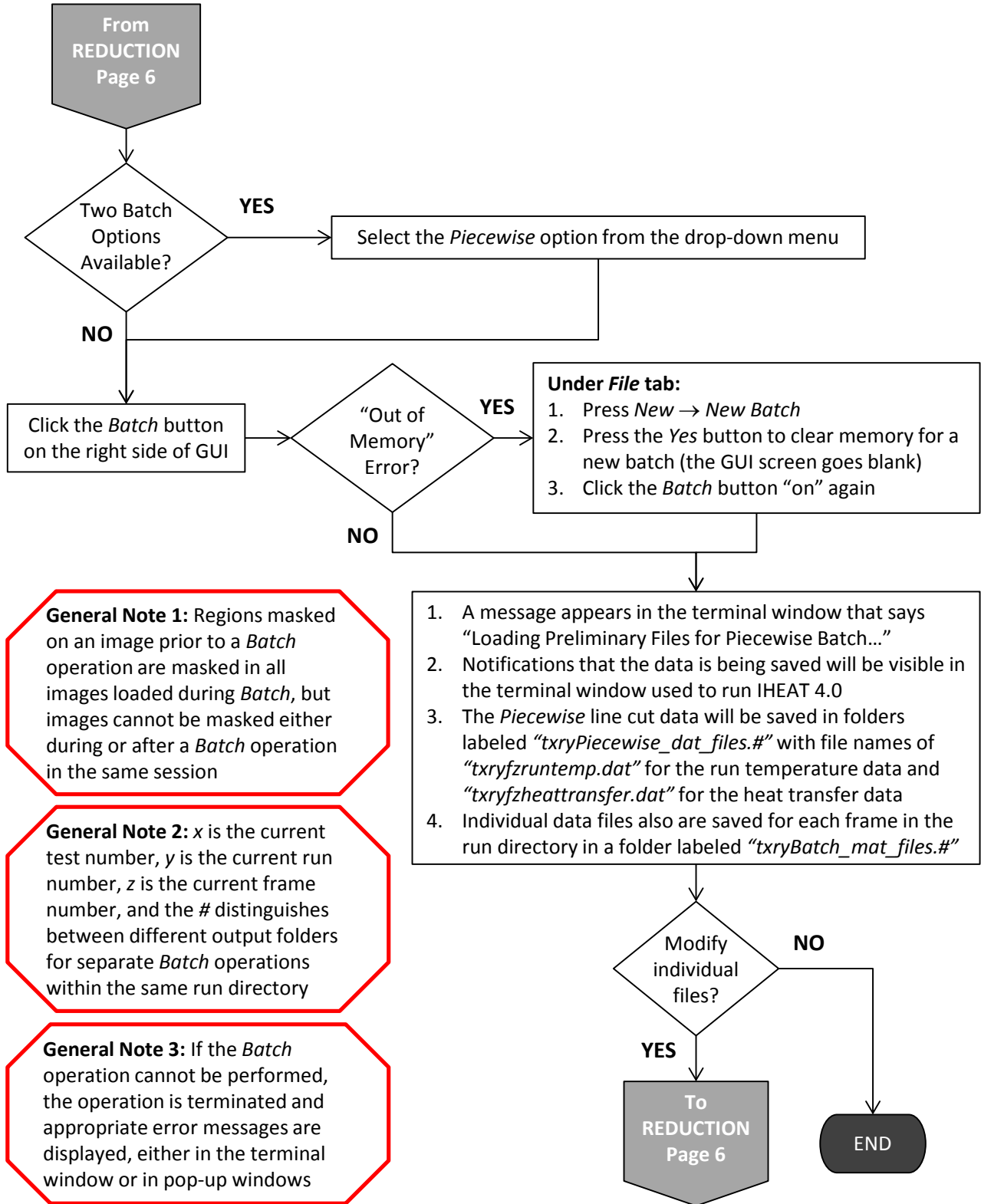
AUTO CUTS

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



MANUAL BATCH

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



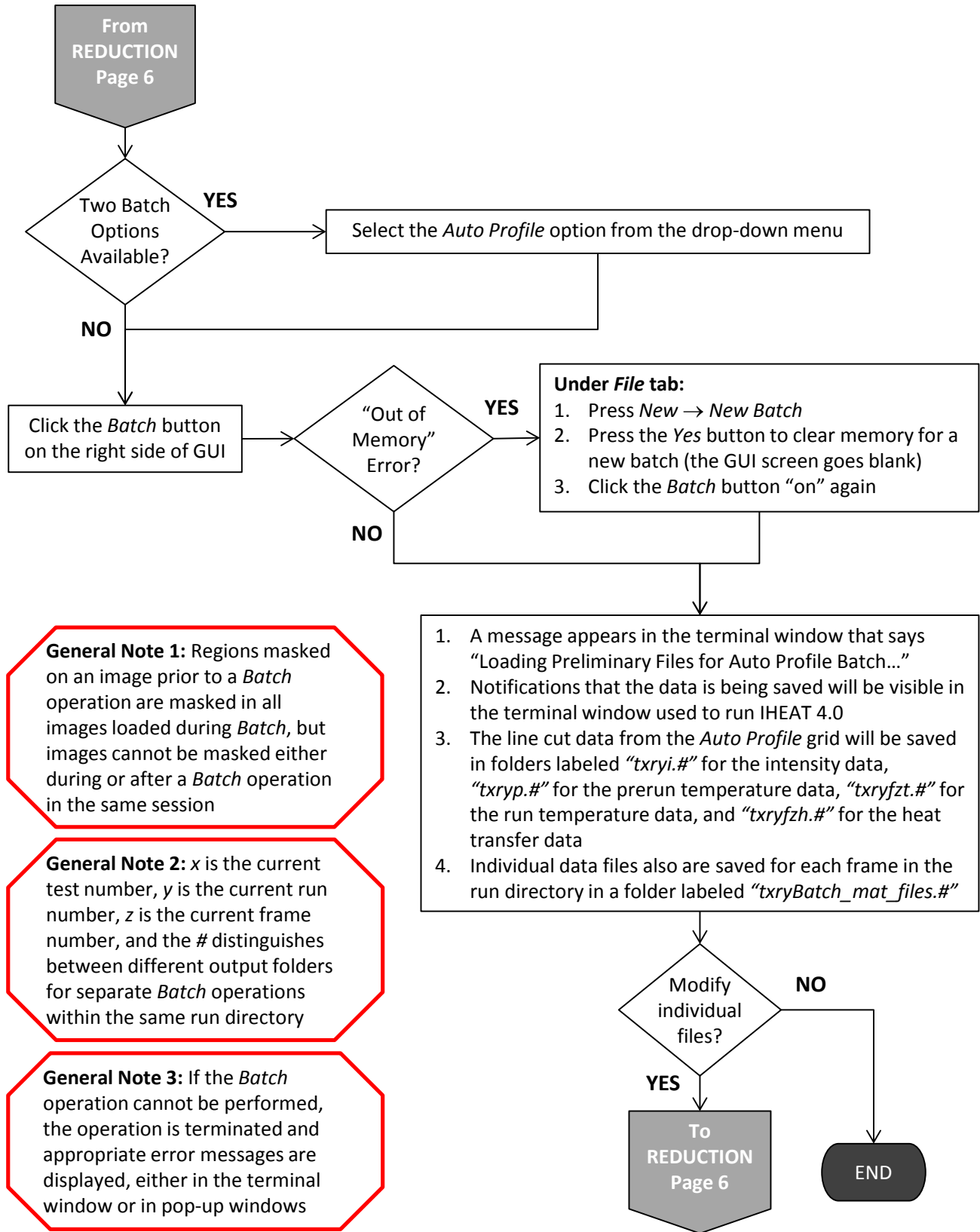
General Note 1: Regions masked on an image prior to a *Batch* operation are masked in all images loaded during *Batch*, but images cannot be masked either during or after a *Batch* operation in the same session

General Note 2: x is the current test number, y is the current run number, z is the current frame number, and the # distinguishes between different output folders for separate *Batch* operations within the same run directory

General Note 3: If the *Batch* operation cannot be performed, the operation is terminated and appropriate error messages are displayed, either in the terminal window or in pop-up windows

AUTO BATCH

PROCEDURE TO RUN IHEAT 4.0 FOR A THERMOGRAPHIC PHOSPHOR TEST



General Note 1: Regions masked on an image prior to a *Batch* operation are masked in all images loaded during *Batch*, but images cannot be masked either during or after a *Batch* operation in the same session

General Note 2: x is the current test number, y is the current run number, z is the current frame number, and the # distinguishes between different output folders for separate *Batch* operations within the same run directory

General Note 3: If the *Batch* operation cannot be performed, the operation is terminated and appropriate error messages are displayed, either in the terminal window or in pop-up windows

3.4. Troubleshooting Guidelines:

The following guidelines provide instructions on how to avoid some of the most common user errors that cause problems in running IHEAT v4.0.

1. Remember to change the location of the .dat look-up table (LUT) in the set-up file prior to reducing a run.
2. If the *Length*, *Profile*, *Piecewise*, *Mask*, *Data* or *Stats* tool is opened, the user must place the appropriate object (such as a rectangle in the *Mask* tool) in the GUI window prior to exiting the tool.
3. When the run temperature image must be both masked and shifted, first shift the run image and then use the *Mask* function (since the masked region does not move as the image is shifted).
4. Do not click on the *Fiducials* tool immediately after the reference line is specified in an initial *Auto Profile* process since the *Fiducials* tool is automatically entered; clicking the *Fiducials* button during the initial “while” loop will cause an error in saving the *Auto Profile* data.
5. The user should not change the run folder while the *Length*, *Profile*, *Piecewise*, or *Print Data* tools are running since the run folder variable is not saved properly when the user changes this string during the while loop in these tools.
6. Do not try to save data to a file that is already open (for example, do not rerun *Batch* while a file output by *Batch* in the same folder is open, since IHEAT will display an error since the software cannot overwrite the file).

Refer to the best practices section in this user manual for solutions to other common errors in the data reduction process. If necessary, contact the authors of the IHEAT 4.0 user manual for additional assistance. Contact Michelle Mason at 757-864-8516 or michelle.mason@nasa.gov, or contact Shann Rufer at 757-864-1005 or shann.j.rufer@nasa.gov.

4. Best Practices

The process of debugging the IHEAT software will continue as new tools are implemented and old modules are updated to be more efficient and user friendly. Certain errors in running IHEAT v4.0 can be anticipated as users become acquainted with the 4.0 version of the software. Software best practice guidelines are outlined below to help new users avoid known pitfalls.

1. The user must ensure the location of the LUT in the set-up file for the current run is correct on the local system. If the set-up file contains a path to a LUT **.dat** file that is stored in another user's directory, the software may not have permission to access that file to compute temperatures in the IHEAT v4.0 images.
2. The user must make sure the LUT path points to a **.dat** version of a LUT, rather than the obsolete **.lut** file type from the legacy 3.2 version of IHEAT. If data from a test conducted prior to 2015 must be re-reduced in IHEAT v4.0, the **.lut** file for the LUT first must be converted to a **.dat** file that can be read into IHEAT v4.0. All of the existing LUT files that were formatted for IHEAT v3.2 have been converted to a format that is usable in IHEAT v4.0 using a separate script. To obtain one of these converted files, consult the authors of this report.
3. The user should be careful not to use the *Load LUT* tool to apply a LUT to a temperature image that differs from the LUT specified in the set-up file for that run. Only the LUT that corresponds to the acquired phosphor thermography data should be used in the quantitative data reduction. The reason the *Load LUT* tool exists is to simplify the process to check new LUTs when calibrations are performed for new batches of the phosphor mix.
4. The user cannot exit an *Auto Profile* operation while setting fiducial marks without causing an error (unless the reference line and the two initial x and y fiducial mark values are already defined). For now, this problem is addressed by printing a warning message when the user begins defining the reference line and the fiducial marks. If the user exits the *Auto Profile* tool prematurely, he or she will encounter an error and will have to restart the IHEAT v4.0 software to complete an *Auto Profile* analysis.
5. The user may encounter errors in the *Auto Profile* tool if fiducials that are in close proximity to each other and are assigned similar x/L or y/y_{ref} values are not carefully defined. If line cuts in the grid are either left out or drawn incorrectly when these similar fiducial marks are defined, either (1) use fewer or different fiducial marks in the analysis to avoid using the similar marks, or (2) move one of the fiducial marks one or two pixels away from the previously defined location to make sure the grid is defined correctly.
6. The user must remember to click *New Batch* prior to conducting a *Batch* operation to make sure enough memory is available to compute and to save all of the data for the images in the run folder. More memory is available on the server than on many personal computers, but conducting *Batch* operations in folders with at least 100 run images can quickly overwhelm any system if the memory is not cleared periodically.

7. The user must confirm that the correct flow conditions, position gauge, and image files are copied to the run folder prior to performing a *Load Run* or a *Batch* operation. If the wrong **.tekflw** or **.tif** files are in the folder, an error will occur during the process of matching up those files when either the *Load Run* or the *Batch* operation are attempted.
8. The user should not rename run or prerun temperature image files or change the extensions on the set-up (**.ihs**), flow conditions (**.tekflw**), or position gauge (**.tektxt**) files to ensure that the automated algorithm in the *Batch* process functions correctly. Additionally, the naming convention for the image files is case sensitive.
9. Prior to a *Batch* operation, the user should ensure that no additional **.tif** images are stored in the run folder aside from the run and prerun temperature images. Other **.tif** files can be stored to the folder as needed if the *Batch* operation is not required, but the automated process for finding run and prerun temperature images will not function properly if additional **.tif** files are stored in the same run folder prior to using the *Batch* tool.
10. The *Batch* operation takes a lot of memory and is operated within the compiler runtime module and should not be interrupted. The user should be careful not to click on other tools within IHEAT while a *Batch* process is running. A separate instance of IHEAT can be opened while a *Batch* operation is conducted, but the user should exercise caution to avoid exceeding the available memory on the system.
11. The user should not open “combined” line cut files generated via a *Batch* process before the *Batch* operation has been completed. Opening these files prematurely can cause errors as the software tries to access the open file to append additional information to the files.
12. The user must exercise caution when implementing the *Convert Files* tools, since the files in the selected directory will be overwritten with the reformatted files.
13. The user should not use the *Export Cursor Data to Workspace* option associated with the MATLAB[®] built-in data cursor tool since that option does not work correctly in the stand-alone executable IHEAT v4.0 software.
14. If certain toXols are opened, such as *Length*, *Profile*, *Piecewise*, *Mask*, *Data*, or *Statistics*, the user must place the appropriate object (such as a rectangle in the *Mask* tool or a line in the *Profile* tool) in the image window prior to exiting the tool. Otherwise, IHEAT v4.0 will malfunction. The reason for this error is the software expects user input to generate the object once the tool is entered, so IHEAT v4.0 waits for the user input even after the tool is exited.
15. The user should not change the run folder while the *Length*, *Profile*, *Piecewise*, or *Print Data* tools are running. These tools use while loops to continuously update the positions of the lines or data points required in each case. The *Run Folder* variable is not saved properly when the user changes this string during the while loop. In future iterations of IHEAT v4.0, this variable will be disabled when those tools are accessed.

16. The user should not continue to use the same instance of IHEAT v4.0 after an error occurs. Instead, the user should save any processed data, then restart the software. Errors in the software sometimes compound and create problems that would not occur if the first error was not in memory.

5. Ongoing Development

IHEAT v4.0 will be upgraded to include additional features that are currently under development or in the beta stage of testing. One tool that is in the beta-testing stage is the three-dimensional (3D) mapping tool. An extrapolation-to-flight module also has been added to IHEAT v4.0, but this tool is only in the alpha testing phase. Another planned module will compute heating data from infrared radiation (IR) temperature data. Addendums to this report will explain how to use the debugged versions of new IHEAT tools to reduce aeroheating data obtained via phosphor thermography or IR.

6. References

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2. Merski, N. R., “Reduction and Analysis of Phosphor Thermography Data with the IHEAT Software Package,” AIAA Paper 98-0712, Jan. 1998.
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4. Wright, S. A. and Berger, K. T., “DAS Procedure for Conducting a Thermographic Phosphor Test,” NASA Langley Aerothermodynamics Laboratory, Hampton, VA (internal report).
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REPORT DOCUMENTATION PAGE

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14. ABSTRACT The Imaging for Hypersonic Experimental Aeroheating Testing (IHEAT) v4.0 thermography data processing code is a new version of a program developed to obtain global heat transfer information from models in the NASA Langley Aerothermodynamics Laboratory (LAL) facilities. This user manual describes the purpose and the features of the new program. A tutorial and a flow chart are included in the manual that describe the program's available tools and detail the steps of the phosphor thermography data reduction process implemented in IHEAT v4.0.					
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