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Videogrammetric Model Deformation Measurement Software Package

Reference Manual for MDef.exe

Kenneth H. Cate
Langley Research Center, Hampton, Virginia
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Overview

Description

The Video Model Deformation (VMD) software package (MDef.exe or MDef) was written as an MS-DOS application for use with an Epix Model-12 video capture card. MDef.exe can capture images in the Epix card’s memory, locate light or dark targets (a.k.a. blobs) within the images, and compute the XYZ displacements for each target. When enabled, MDef can also compute the amount of twist along specified rows of targets.

Minimum System Requirements

IBM PC style computer (80286 processor or better)
Motherboard with two, adjacent, full-length card slots with no obstructions
Epix Model 12 video capture card
Epix type video breakout connector (1DB25)
Video camera (pixel-clock output recommended) with power supply
Black and white (B&W) or color monitor for viewing video output from the Epix card
Two RG-59 cables (one for video signal from camera to Epix card, the other for video signal to monitor)
Retro-reflective material or paint for targets

Optional Parts

IBM PC style computer (80286 processor or better)
Mounting hardware for camera
RG-59 cable for pixel-clock signal from camera to Epix card (if this signal is available)
B&W or color monitor for viewing video input to Epix card
RG-59 cable for 2nd monitor
Light source (variable intensity recommended) such as fiber optic bundle
Variable power supply for controlling light source remotely
Cable for connecting power supply to light source
Ethernet card and cable for network connection

Other parts may be needed depending on if wind-tunnel data is being sent to the VMD system, and the method of transfer (such as by RS-232 or a network connection).

Hardware Connections

All video and pixel-clock signals are routed through RG-59 (75 ohm) co-axial cable. Connect the Video output from the camera to the video input of a B&W monitor then connect the output from the monitor to the video input lead of the Epix card (labeled VIN). If the camera has a pixel-clock output (a continuous signal of approximately 14.318MHz), it is connected to the external clock input lead of the Epix card (labeled CLOCK_IN). The video output lead of the Epix card (labeled GREEN) is connected to the video input of the second B&W monitor.
Trigger Connection

The Epix card has a trigger input lead (labeled EXT_IN) that can be used to trigger data taking. The trigger is a TTL level signal with a high to low transition. Since EXT_IN floats high (~5V), a simple short to ground (0V) is all that is needed as a trigger signal.

An alternate method of triggering data taking is via a network connection to the Data Acquisition System (DAS) at the facility where the test is being held. A network connection requires the computer to have an Ethernet card installed, and network addresses to be assigned to the computer and the network port that is to be monitored. When MDef is started with the proper command-line options, it will establish a network connection with the DAS; MDef will then pole the DAS several times a second to determine when to take data.

Data Acquisition System (DAS) Interface

The serial port on the computer can be used to receive wind tunnel data through a standard RS-232 cable. An external program is written to open the port, read the data stream, close the port, write the data to a copy of Video.dat (See Appendix), and then return to the calling program. The batch file GetFile.bat is used to call the external program.

RS-232 Connection

The serial port on the computer can be used to receive wind tunnel data through a standard RS-232 cable. An external program is written to open the port, read the data stream, close the port, write the data to a copy of Video.dat (See Appendix), and then return to the calling program. The batch file GetFile.bat is used to call the external program.

Network Connection

An Ethernet connection can be used to receive wind tunnel data as well as triggering data taking. After the computer has been assigned an IP address on the network, MDef.exe can be called with the appropriate IP address and Port number for the Data Acquisition System server.

Software Setup

The VMD code (MDef.exe) is normally stored (along with other useful programs) in a directory named Facility\Code off the root directory of one of the hard drives (Ex.: C:\Facility\Code). This directory is usually added to the search path in Autoexec.bat. A Facility\Plates directory is also used as a place for storing the calibration plate data files. Directories are created in the Facility directory named after the facility where a test is being held (such as TDT for the Transonic Dynamics Tunnel). Work (or test) directories are created in the appropriate facility directory.

If the test number was 542 and a conventional wing was being tested at the Transonic Dynamics Tunnel (TDT), the work directory might be:

C:\Facility\TDT\T542.CON
Since MDef.exe was written as a DOS application, all file names and directory names need to be kept short (8 characters for a name, a period, and 3 characters for an extension). MDef.exe creates special directories for its output files within the work directory, as they are needed for the output files.

### Necessary Files

- **MDef.exe** The main VMD program
- **Param.dat** The test configuration file; See Appendix for sample
- **FlapAngl.ini** Flap and wing angle configuration file

### Miscellaneous Files

**Note:** * denotes a file or program that may not be needed for the normal operation of MDef

** denotes a file that may be needed by the DAS

- **GetFile.bat** DOS batch file used to obtain the wind tunnel data when a socket connection is not used
- **For-A.exe** Reads a stream of RS-232 data and uses it to create a copy of Video.dat
- **For-A.ini** Configuration file used by For-A.exe
- **MDef.send** Sample script file used by the DAS to format and send data to MDef via a socket connection
- **ReRun.exe** Re-processes the target data using a modified copy of Param.dat
- **ReDoFlap.exe** Re-processes the Flap-Angle data (FlapAngl.txt) using a modified copy of FlapAngl.ini

### Param.dat

The configuration file **Param.dat** is a simple text file containing information about the placement and orientation of the video camera, the image size to be used, the maximum and minimum target sizes, the number of targets to search for, and other information needed by MDef. Most of the lines in Param.dat can contain comments (which are ignored by MDef).

### FlapAngl.ini

The flap and wing angle configuration file **FlapAngl.ini** is a simple Windows® type INI file specifying which targets are grouped into ‘rows’ for computing wing twist or angle-of-attack (AOA). FlapAngl.ini also identifies the row to be used as a reference and the correction values used in the computations.

### GetFile.bat

MDef calls GetFile.bat when it needs to retrieve the wind tunnel data. GetFile.bat is either set up to copy a file off a shared drive to Video.dat (in the current work directory) or it calls another program (such as **FOR-A.exe**) to read the tunnel data from an **RS-232** stream and write the data to a copy of Video.dat.
For-A.exe

When the wind tunnel data is being sent to MDef over an RS-232 cable, FOR-A.exe (or a similar program) can be called by GetFile.bat. For-A reads a stream of RS-232 data and uses it to create a copy of Video.dat in the current directory.

For-A.ini

The configuration file For-A.ini is used by For-A to identify what characters (or words) in the RS-232 stream to use to identify the wind tunnel data. For-A can be used as a stand-alone program to continuously read and display the wind tunnel data. Labels can be added to For-A.ini to be used when displaying the data.

Work Directory Structure

When the VMD code (MDef.exe) is run, sub-directories are created in the work directory for the output files but only when data is to be written. The directories that MDef creates and uses are:

- Centroid\ Centroid data files are saved here (Centxxxx or Cerrxxxx)
- XYZ\ XYZ data files are saved here (XYZxxxxx)
- ZSLP\ Z-Intercept/Slope files are saved here (ZSLPxxxx)
- Images\ RAW and TIFF image files are saved here

The use of ‘xxxx’ in a file name designates a number that is padded with leading zeros so that the file name is eight characters long and the numeric part appears right justified such as Cent0025. If MDef is triggered to take data but the point number has not advanced, padded numeric extensions are added to the file names to prevent overwriting previous data. Example: If MDef were triggered to take data for point number 25 a second time, the new centroid file would be named Cent0025.001. The XYZ and ZSLP files are named similarly. The reason for padding the file names with zeros is to make sorting easier.

Output Files

MDef creates several output files. When wind-tunnel data is read, a copy of the data is written to Tunnel.log. When data is taken, the centroid locations within the image plane (in pixels) are written to the temporary file Blobs.dat. If any row of targets does not contain the proper number of targets, Blobs.dat is copied to a Cerr type file (ex: Cerr0025) in the Centroid directory. Any ‘good’ rows are written to a Cent type file (ex: Cent0025) in the Centroid directory.

Computations are made to using the ‘good’ centroid locations to determine the X, Y, and Z locations of the targets in 3-dimensional space; the results are written to a XYZ type file in the XYZ directory. Averaged X, Y, and Z values for all fields are written to XyzMean.dat in the work directory. The slope (or angle-of-attack) of each row is calculated, along with the Z-axis displacement and standard-of-deviation values, and written to Zintslpe. Sample output files can be found in the appendix.

Initial Setup

Before MDef can be used for a new test, the configuration file Param.dat must be created. The following is a line-by-line description of the file.
<table>
<thead>
<tr>
<th>Line</th>
<th>Value (Ex.)</th>
<th>Parameter Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Tab point Used as a starting value for the point numbers when either Video.dat or a socket connection is not available. A negative point number indicates that flap-angle computations are to be done; otherwise, MDef defaults to a Zintslpe display. If the ASCII character 124 ('I') is placed on this line, the text following the character is used as a title for the test.</td>
</tr>
<tr>
<td>2</td>
<td>752</td>
<td>Horizontal pixels The image dimensions used by the Epix card (normally 752 X 240 for non-interlaced images). If a full image is not desired, the horizontal and vertical offsets (in pixels) of the portion of the image to capture is given on lines 3 and 5, respectively.</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>Horizontal offset Normally 0, use -1 to center the captured region.</td>
</tr>
<tr>
<td>4</td>
<td>240</td>
<td>Vertical pixels Maximum = 2401, 480 if interlace is ON.</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>Vertical offset Normally 0, use -1 to center the captured region on the screen.</td>
</tr>
<tr>
<td>6</td>
<td>0.026</td>
<td>Vertical pixel spacing of camera in mm The spacing of the camera’s pixels in millimeters. For a Hitachi model KP-M1U CCD camera, the numbers are approximately 0.026 vertical, and 0.011 horizontal.</td>
</tr>
<tr>
<td>7</td>
<td>0.011</td>
<td>Horizontal pixel spacing of camera in mm</td>
</tr>
<tr>
<td>8</td>
<td>363.2</td>
<td>Pixel x principal point To be measured during configuration.</td>
</tr>
<tr>
<td>9</td>
<td>100.5</td>
<td>Pixel y principal point To be measured during configuration.</td>
</tr>
<tr>
<td>10</td>
<td>362</td>
<td>Pixel x symmetry point Measured by zoom symmetry on image.</td>
</tr>
<tr>
<td>11</td>
<td>101</td>
<td>Pixel y symmetry point Measured by zoom symmetry on image.</td>
</tr>
<tr>
<td>12</td>
<td>0.0</td>
<td>K1 radial distortion mm^-2 The K1 radial distortion factor in mm^2. If any of the variables K2, K3, P1 or P2 are needed, they can be inserted between this line and the next. The extra variables are added in order. Any unneeded variables in the set MUST be inserted and set to zero. If only K2 and P1 are needed, values for K2 and K3 must be included.</td>
</tr>
<tr>
<td>13</td>
<td>1.0</td>
<td>Unitless sh_ratio locked/unlocked</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>Pixel x shift unlocked to locked</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>Pixel y shift unlocked to locked</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>Delta_x How much to increase the target bounding box over the default minimum of 4.</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>Delta_y How much to increase the target bounding box over the default minimum of 2. When targets (or blobs) are found, a rectangular area surrounding the target is determined. The background level is measured along the top and bottom edges and is subtracted from the entire rectangle. The box size can be adjusted with the values Delta_x and Delta_y.</td>
</tr>
<tr>
<td>18</td>
<td>12.7</td>
<td>Camera constant c in mm</td>
</tr>
<tr>
<td>19</td>
<td>57.9047</td>
<td>Deg omega Camera's rotation (orientation) about the X-axis within the wind tunnel.</td>
</tr>
<tr>
<td>20</td>
<td>180.1271</td>
<td>Deg phi Camera's rotation about the Y-axis within the wind tunnel.</td>
</tr>
<tr>
<td>21</td>
<td>89.0504</td>
<td>Deg kappa Camera's rotation about the Z-axis within the wind tunnel.</td>
</tr>
<tr>
<td>22</td>
<td>-5.4308</td>
<td>Inch Xc Camera's position in relation to the model in inches (along air flow axis).</td>
</tr>
<tr>
<td>23</td>
<td>28.5556</td>
<td>Inch Yc Camera's horizontal position in relation to the model in inches.</td>
</tr>
<tr>
<td>24</td>
<td>-27.3561</td>
<td>Inch Zc Camera's height in relation to the model in inches.</td>
</tr>
</tbody>
</table>
| 25   | 1           | White-on-black 0 = Dark targets on light background, else Light targets on a
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>12</td>
<td><strong>Minimum_blob_mass</strong> Minimum number of pixels in a valid target.</td>
</tr>
<tr>
<td>27</td>
<td>4</td>
<td><strong>Fields delay</strong> If &lt;= 0, get tunnel data AFTER scanning for blobs. Some video capture cards require a few fields to be skipped after a hardware trigger before images are captured. The fields delay determines the number of fields to skip. The sign on this number is used to control when the wind tunnel data is read.</td>
</tr>
<tr>
<td>28</td>
<td>60</td>
<td><strong>Target threshold</strong> Gray-scale level for detecting targets; see White-on-black.</td>
</tr>
<tr>
<td>29</td>
<td>10</td>
<td><strong>Maximum buffers to process</strong> When set to 0, MDef computes this value based on the image size and size of the Epix card’s memory.</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td><strong>Skip buffer offset</strong> When set to 0, MDef processes every buffer. A value of 5 would cause MDef to process the fields in the sequence: 1, 7, 13, etc.</td>
</tr>
<tr>
<td>31</td>
<td>0</td>
<td><strong>Row orientation</strong> If less than 0, MDef does not sort the targets into rows. If set to 0, MDef sorts the targets into vertical rows, else horizontal.</td>
</tr>
<tr>
<td>32</td>
<td>2</td>
<td><strong>Number of rows of targets</strong> The targets are aligned as rows running parallel to the model’s center axis. This number sets the number of rows for sorting, etc.</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td><strong>Row 1 Information</strong> Start of information describing the target rows. This line is plain text.</td>
</tr>
<tr>
<td>34</td>
<td>11</td>
<td><strong>Number of targets on Row 1</strong></td>
</tr>
<tr>
<td>35</td>
<td>1.0</td>
<td><strong>Y/b/2</strong> (Row 1) The normalized semi span offset.</td>
</tr>
<tr>
<td>36</td>
<td>0.0</td>
<td><strong>z ref offset</strong> (Row 1) See equation below</td>
</tr>
<tr>
<td>37</td>
<td>0.0</td>
<td><strong>AOA ref offset</strong> (Row 1) See equation below</td>
</tr>
<tr>
<td>38</td>
<td>1.0</td>
<td><strong>Z ref slope</strong> (Row 1) See equation below</td>
</tr>
<tr>
<td>39</td>
<td>1.0</td>
<td><strong>AOA ref slope</strong> (Row 1) See equation below</td>
</tr>
<tr>
<td>40</td>
<td>3</td>
<td><strong>Ref point</strong> (Row 1) Point within a row to use to determine z_int; can be a fraction to specify a position between two targets.</td>
</tr>
<tr>
<td>41</td>
<td></td>
<td><strong>Row 2 Information</strong></td>
</tr>
<tr>
<td>42</td>
<td>11</td>
<td><strong>Number of targets on Row 2</strong></td>
</tr>
<tr>
<td>43</td>
<td>2.0</td>
<td><strong>Y/b/2</strong> (Row 2) The normalized semi span offset.</td>
</tr>
<tr>
<td>44</td>
<td>0.0</td>
<td><strong>z ref offset</strong> (Row 2) See equation below</td>
</tr>
<tr>
<td>45</td>
<td>0.0</td>
<td><strong>AOA ref offset</strong> (Row 2) See equation below</td>
</tr>
<tr>
<td>50</td>
<td>1.0</td>
<td><strong>Z ref slope</strong> (Row 2) See equation below</td>
</tr>
<tr>
<td>55</td>
<td>1.0</td>
<td><strong>AOA ref slope</strong> (Row 2) See equation below</td>
</tr>
<tr>
<td>60</td>
<td>3</td>
<td><strong>Ref point</strong> (Row 2) Point within a row to use to determine z_int; can be a fraction to specify a position between two targets.</td>
</tr>
</tbody>
</table>

When targets (blobs) are found, a rectangular area surrounding the target is determined. The background level is measured along the top and bottom edges and is subtracted from the entire rectangle. The box size can be adjusted with the values Delta_x and Delta_y.

Some video capture cards require a few fields to be skipped after a hardware trigger before images are captured. The fields delay (line 27) determines the number of fields to skip. The sign on this number is used to control when the wind tunnel data is read: before or after the captured images are processed.

After targets are found within an image, they are sorted to determine their order. When multiple regions are used, sorting may not be required.

The information in the ‘ROW x INFORMATION’ tables is used to compute the angle of the ‘row’ and the z-displacement of a specific target. The equations are:
\[ z_{\text{int}} = (\text{intercept} - z_{\text{ref}}) \cdot z_{\text{ref\_slope}} \]
\[ \text{angle} = (\text{aoa} - \text{aoa_{ref}}) \cdot \text{aoa_{ref\_slope}} \]

After all of the Row tables is found a table of miscellaneous information starting with a header line.

<table>
<thead>
<tr>
<th>Thres</th>
<th>nw.x</th>
<th>nw.y</th>
<th>minx</th>
<th>miny</th>
<th>maxx</th>
<th>maxy</th>
<th>yref[]</th>
<th>compl</th>
<th>bac_sub</th>
<th>add_sub</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>35</td>
<td>30</td>
<td>4</td>
<td>2</td>
<td>21</td>
<td>11</td>
<td>0.00000</td>
<td>0</td>
<td>1</td>
<td>-3</td>
<td>0.00000</td>
</tr>
</tbody>
</table>

Columns 8, 12, and 13 are used to specify the locations of each target in the order that they are placed in after located and then sorted. The rest of the columns are used to specify information for the search region(s). If the entire image is to be used as the first and only region, the first threshold value in this table is set to a negative value. The default threshold value on line 28 will be used instead but columns 4 through 14 will be used as usual.

The columns are:

<table>
<thead>
<tr>
<th>Column</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thres</td>
<td>The threshold value for a search region (region of interest) within an image. A positive value here overrides the default threshold (line 28 above). A negative value marks the end of the search region information within this table. The number of consecutive positive threshold values determines the number of regions.</td>
</tr>
<tr>
<td>2, 3</td>
<td>nw.x, nw.y</td>
<td>The area of interest boundaries, in pixel numbers for a search region within an image. nw.x and nw.y designate the &quot;north-west&quot; or upper-left boundary. sw.x and sw.y designate the &quot;south-west&quot; or upper-left boundary.</td>
</tr>
<tr>
<td>4, 5, 6, 7</td>
<td>minx, miny, maxx, maxy</td>
<td>The maximum and minimum sizes for the targets within each search region. If the entire image is used as a single region, the first set of these values is used as the default</td>
</tr>
<tr>
<td>8</td>
<td>y-ref</td>
<td>The target's Y-reference value. Each target’s y-ref is indicated. This value is the distance of each target from the centerline of the model, in inches.</td>
</tr>
<tr>
<td>9</td>
<td>compl</td>
<td>This value determines if the pixels within the rectangle bounding a target are to be complemented.</td>
</tr>
<tr>
<td>10</td>
<td>bac_sub</td>
<td>This value determines if the background is to be subtracted from every pixel in the target rectangle.</td>
</tr>
<tr>
<td>11</td>
<td>add_sub</td>
<td>An additional value to subtract from the pixels in the target rectangle.</td>
</tr>
<tr>
<td>12</td>
<td>X</td>
<td>The targets' X-reference value in inches.</td>
</tr>
<tr>
<td>13</td>
<td>Z</td>
<td>The targets' Z-reference value in inches.</td>
</tr>
<tr>
<td>14</td>
<td>Mtar</td>
<td>The maximum number of targets to be found in this search region. When this number is reached, MDef begins searching for targets in the next region.</td>
</tr>
<tr>
<td>15, 16</td>
<td>se.x, se.y</td>
<td>The location (in pixel numbers) defining the boundary of the “south-east” corner of a search region.</td>
</tr>
</tbody>
</table>
MDef Operation

When started, MDef reads Param.dat. If the number on the first of Param.dat is negative, MDef reads FlapAngl.ini. MDef then sets the Epix card to the configuration specified in Param.dat. If the network address and port number are given, MDef attempts to establish a connection to the Data Acquisition System. MDef next reads the current wind-tunnel information, and sets up the normal operation display (See Figure 1).

![Figure 1 - Sample Start-up Screen Showing the Flap-Angle Display](image)

MDef can be started with various command-line options. A list of command-line options can be obtained by starting MDef with a command-line option of ‘?’ or ‘-?’ (Ex.: MDef.exe ?). The command-line options are:

- 
  -F - Load a still image file for processing instead of capturing and processing new images
  -A - IP Address for network access to the Data Acquisition System (DAS)
  -P - Port number for network access to the Data Acquisition System (DAS)
  -E - Disable External Triggers (can be enabled and disabled from within MDef)
  -U - Disable Pixel-Clock Lock (Unlock; can be enabled and disabled from within MDef)
  -I - One-Shot operation, Take one (1) data point and quit
  ? - Display a list of command-line options

The -F, -A, and -P options are followed by colons and the appropriate information, such as:


It should be noted that MDef only loads 8-bit grayscale image files that are uncompressed and have no header such as the images that MDef creates with the Save-Image command (ALT-S). Consecutive image files are loaded into consecutive image buffers starting with buffer one.
Some of the user controllable options are displayed on the second line of the screen with ‘hot keys’ highlighted. Function key **F1** can be used to pull up a scrollable help screen. Normal data taking can be manually triggered by pressing the letter **T**. A sample image can be captured and processed without writing to any of the append files by pressing the letter **B**; this is what is referred to as a ‘B’ test as ‘Boxes’ are drawn around any regions of interest after the targets are located. The ‘B’ test also numbers the targets and the regions (See Figure 7). The ‘B’ test is frequently used to confirm that the targets are within the proper image search region(s), the maximum and minimum blob sizes are set correctly, and the thresholds are set correctly for each search region.

- **B**: Do a 1-Shot Blob Test, number the targets found, draw boxes around each search region
- **C**: Toggle Pixel-Clock Lock
- **E**: Toggle External trigger enable
- **F**: Toggle between Flap-Angle data display and AOA data display
- **I**: Toggle Independent blob tracking
- **K**: Toggle Blob tracking (not normally used in this version of MDef)
- **L**: Toggle Live video mode
- **P**: Toggle Auto increment of Point number
- **Q**: Quit this program
- **R**: Toggle Real-time image capture
- **T**: Take data (Manual trigger)
- **W**: Walk (Step) through the image buffers
- **Z**: Zero the Wing and Flap-Angle data

**ALT-F**: Toggle Flap-Angle computations enable
**ALT-L**: Change LUX (threshold) setting for any region
**ALT-S**: Save current image buffer as a raw image file and as a TIFF file
**ALT-U**: Update the parameter file

The up and down arrow keys can also be used to change the image buffer being viewed.
When MDef runs, two types of result displays are available for viewing. One display is the newer Flap-Angle display (as shown in Figures 1 and 3), and the other display is the older Z-Intercept / Slope (Zintslpe) display (as shown in Figure 2).

![Sample Flap-Angle Display](image)

Figure 3 – Sample Flap-Angle Display

The green bar on the screen, and the text on the line immediately below it, displays some of the information from the wind tunnel’s Data Acquisition System (DAS). The wind tunnel data can be obtained by accessing a file on a shared drive, reading serial data from an RS-232 stream from the DAS, or by a network connection to the DAS. MDef can also read the tunnel directly from the DAS by a ‘socket’ connection over the network.

### Serial Connection

If a serial connection is used, the DAS must be set up to send data continuously over an RS-232 cable to the computer that is running MDef. A copy of `GetFile.bat` is written that calls a program, such as `For-A.exe`, which can read the RS-232 stream and write the data that it receives to a copy of `Video.dat` in the work directory of the MDef computer. A configuration file (For-A.ini) must be set up for the program to know how to interpret the RS-232 stream in order to write `Video.dat`.

### Network Connection

The computer on which MDef is being used must be set up with an Ethernet connection and properly configured (local IP address, etc.). If the wind tunnel data is being written to a shared drive, the data must be in the same format as `Video.dat`. A copy of `GetFile.bat` is written that copies the data file from the shared drive to `Video.dat` in the work directory of the MDef computer.
Socket Connection

The MDef computer is set up the same way as for a simple network connection. MDef must be run with the command-line options for the DAS IP address and a valid port number to talk directly to the DAS. The DAS must also be set up to send the required data in a specific order (See MDef.send in the Appendix).

Figure 4 – Sample ‘Step’ Calibration Plate
Figure 5 – Sample ‘Step’ Calibration Plate with Illumination

Figure 6 – Sample Image with Targets Located by ‘B’ Test Using a Single Region
Setup Procedure

Camera Setup and Orientation

The video camera is mounted on a fixed bracket or pan-tilt mechanism behind the wall of a wind tunnel’s test section so that it views the model through a window. The camera is rotated 90 degrees so that the flow direction is vertical on the image plane as seen on the monitors. A variable intensity light source is usually placed near the camera to illuminate the retro-reflective (or white) targets and is adjusted, along with the aperture setting on the camera, to produce a high-contrast image of the targets on the monitors. In addition to the usual bright targets on a dark background, MDef can be set up for dark targets on a light background. Set **White-on-black** (line 25 in Param.dat) for the default, or set the flags in the **compl** column (lines 42+) for each region.

Configuration

Initial values for the camera’s location are obtained by measuring the camera’s location with respect to the model. The Y value (line 22 of Param.dat) is the distance (in inches) from the camera to the model along a horizontal line perpendicular to the centerline of the wind tunnel. The sign of Y is positive if the camera is on the right side of the model (air flow is to the left when viewed by someone standing next to the camera facing the model). The Z value (line 23 of Param.dat) is the vertical displacement of the camera from the centerline of the model. A positive value of Z implies that the camera is above the centerline of the model. The X value (line 21 of Param.dat) is the distance the camera is behind target number one on the model and is frequently less than ten inches.
Since the camera is usually rotated 90 degrees along its line of sight, the initial value for kappa is (line 21 of Param.dat) set for 90. Omega (line 19) is the camera’s rotation around the axes parallel to the wind tunnel’s airflow (or the centerline of the model). Phi is the camera’s rotation around a vertical axis.

A target plate (whose target locations have been measured) is placed near the model, within the field of view of the camera (see figure 4), and oriented parallel to the main axes of the wind tunnel. The target plate is usually mounted on a tripod such that the target plate can be translated (moved) at least one inch in along of the three axes. A copy of the target plate’s reference file is created with the targets arranged in the order that they will be detected by MDef. The target nearest the top left corner of the images on the monitors is referred to as target 1, with the target below it referred to as target 2. If horizontal sorting is selected in Param.dat, the target to the right of target 1 is target 2. The X, Y and Z columns in the reference file are arranged to reflect any changes in the target plate’s orientation. One or more columns may need their signs reversed. The values from the new target reference file are copied to the columns in Param.dat labeled yref[], X, and Z.

After the initial values are placed in Param.dat, a ‘B’ (Box) test is performed. Confirm that the targets are being identified properly and that the target plate’s orientation angle is near zero. If some of the targets are not found, any of the following may need to be changed:

1) The lighting (the targets may not be bright enough)
2) The aperture of the lens (there should be sufficient contrast between targets and background)
3) The threshold level(s) in Param.dat (line 28 or column 1 in the region table)
4) The maximum and/or minimum target size(s) in Param.dat (columns 4-7 in the region table)
5) The camera’s orientation (all of the targets must be in the field of view for the entire range of angles the model is to be set during the test)
6) The focal length of the lens (See item #5)

**Distortion**

Additional software is available that can process data files created by MDef (when using a pre-measured target plate) that will calculate the pixel principal point (lines 8 and 9), the pixel symmetry point (lines 10 and 11), as well as the distortion correction value k1 (line 12) for use in Param.dat. Although k1 is placed on line 12 of Param.dat, if the other correction values are needed, they can be added immediately after k1 in the order: k2, k3, p1, and p2.

-1.113e-003 k1 radial distortion mm^-2  (Put K2, K3, P1 & P2 after this ...
0.0  k2 radial distortion mm^-4
1.0000000 Unitless sh_ratio locked/unlocked
Appendix

All output files (with the exception of the image files) are plain text files with header and comment lines prefixed with a percent sign. This allows the files to be loaded into Matlab® for generating special plots.

**Sample Param.dat File**

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-48</td>
<td>Tab Point</td>
</tr>
<tr>
<td>752</td>
<td>Horizontal pixels (Must be divisible by four, Max=752)</td>
</tr>
<tr>
<td>0</td>
<td>Horizontal offset (-1 to center)</td>
</tr>
<tr>
<td>240</td>
<td>Vertical pixels (Max = 240, 480 if interlace On)</td>
</tr>
<tr>
<td>0</td>
<td>Vertical offset (-1 to center)</td>
</tr>
<tr>
<td>0.02599700</td>
<td>Vertical pixel spacing of camera in mm</td>
</tr>
<tr>
<td>0.01099700</td>
<td>Horizontal pixel spacing of camera in mm</td>
</tr>
<tr>
<td>370.00</td>
<td>Pixel x principal point (To be measured during cal)</td>
</tr>
<tr>
<td>108.00</td>
<td>Pixel y principal point</td>
</tr>
<tr>
<td>374.30</td>
<td>Pixel x symmetry point (Measured by zoom symmetry on image)</td>
</tr>
<tr>
<td>107.60</td>
<td>Pixel y symmetry point</td>
</tr>
<tr>
<td>-1.113e-003</td>
<td>k1 radial distortion mm^-2 (Put K2, K3, P1 &amp; P2 after this line if needed)</td>
</tr>
<tr>
<td>1.0000000</td>
<td>Unitless sh_ratio locked/unlocked</td>
</tr>
<tr>
<td>0.00</td>
<td>Pixel x shift unlocked to locked</td>
</tr>
<tr>
<td>0.00</td>
<td>Pixel y shift unlocked to locked</td>
</tr>
<tr>
<td>1</td>
<td>Delta_x (how much to increase the box over min of 4)</td>
</tr>
<tr>
<td>1</td>
<td>Delta_y (how much to increase the box over min of 2)</td>
</tr>
<tr>
<td>12.8950</td>
<td>Camera constant c in mm</td>
</tr>
<tr>
<td>-151.4449156222003</td>
<td>Deg omega</td>
</tr>
<tr>
<td>-3.079673156343532</td>
<td>Deg phi</td>
</tr>
<tr>
<td>-83.94443400192141</td>
<td>Deg kappa</td>
</tr>
<tr>
<td>-1.627920426876803</td>
<td>Inch Xc</td>
</tr>
<tr>
<td>80.248 42.51402182382443</td>
<td>Inch Yc</td>
</tr>
<tr>
<td>-86.09295102229963</td>
<td>Inch Zc</td>
</tr>
<tr>
<td>1</td>
<td>White-on-black (0 = Dark targets, else Light)</td>
</tr>
<tr>
<td>12</td>
<td>Minimum_blob_mass</td>
</tr>
<tr>
<td>4</td>
<td>Fields delay (if &lt;= 0 get tunnel data AFTER scanning for blobs)</td>
</tr>
<tr>
<td>100</td>
<td>Target threshold (difference for White-on-black)</td>
</tr>
<tr>
<td>60</td>
<td>Maximum buffers to process (0 to let it compute number)</td>
</tr>
<tr>
<td>5</td>
<td>Skip buffer offset (0 to process every buffer)</td>
</tr>
<tr>
<td>0</td>
<td>Row orientation (&lt;0 = No sort, 0 = vertical, else horizontal)</td>
</tr>
<tr>
<td>5</td>
<td>Number of rows of targets (See: Ames54b.tdt in plates directory)</td>
</tr>
</tbody>
</table>

**ROW 1 INFORMATION**

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Number of targets on Row 1</td>
</tr>
<tr>
<td>0.0000</td>
<td>Y/b/2 (Row 1)</td>
</tr>
<tr>
<td>0.0000</td>
<td>Z ref offset (Row 1) z_int = (intercept - zref) * zref_slope</td>
</tr>
<tr>
<td>0.0000</td>
<td>AOA ref offset (Row 1) angle = (aoa - aoaref) * aoaref_slope</td>
</tr>
<tr>
<td>1.0000</td>
<td>Z ref slope (Row 1)</td>
</tr>
<tr>
<td>1.0000</td>
<td>AOA ref slope (Row 1)</td>
</tr>
</tbody>
</table>
2.0000  Ref Point  (Row 1) (x.y -> .y after point x)

ROW 2 INFORMATION
3  Number of targets on Row 2
0.406  Y/b/2  (Row 2)
0.000  Z ref offset  (Row 2)
0.000  AOA ref offset  (Row 2)
1.000  Z ref slope  (Row 2)
1.000  AOA ref slope  (Row 2)
2.000  Ref Point  (Row 2) (x.y -> .y after point x)

ROW 3 INFORMATION
3  Number of targets on Row 3
0.535  Y/b/2  (Row 3)
0.000  Z ref offset  (Row 3)
0.000  AOA ref offset  (Row 3)
1.000  Z ref slope  (Row 3)
1.000  AOA ref slope  (Row 3)
2.000  Ref Point  (Row 3) (x.y -> .y after point x)

ROW 4 INFORMATION
3  Number of targets on Row 4
0.724  Y/b/2  (Row 4)
0.000  Z ref offset  (Row 4)
0.000  AOA ref offset  (Row 4)
1.000  Z ref slope  (Row 4)
1.000  AOA ref slope  (Row 4)
2.000  Ref Point  (Row 4) (x.y -> .y after point x)

ROW 5 INFORMATION
2  Number of targets on Row 5
0.850  Y/b/2  (Row 5)
0.000  Z ref offset  (Row 5)
0.000  AOA ref offset  (Row 5)
1.000  Z ref slope  (Row 5)
1.000  AOA ref slope  (Row 5)
1.500  Ref Point  (Row 5) (x.y -> .y after point x)

Thres nw.x nw.y minx miny maxx maxy  yref[] compl bac_sub add_sub  X  Z
Mtar se.x se.y

100  35  30  4  2  21  11  0.00000  0  1  3  0.00000
  0.00000  3  182  240
100  185  10  7  3  21  11  0.00000  0  1  3  0.00000
  0.00000  11  750  238
-128  0  0  7  3  21  11  0.00000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  22.47000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  22.47000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  22.47000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  22.47000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  29.58000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  29.58000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  29.58000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  40.00000  0  0  0  0.00000
    0.00000  0  752  240
-128  0  0  7  3  21  11  40.00000  0  0  0  0.00000
    0.00000  0  752  240
Sample FlapAngl.ini File

; FlapAngl.ini
;
Test= 542
B_2= 55.285
RefAngle= 1 ; Angle to be subtracted from all angles after corrections
;
; Target numbers defining the angles to calculate
;
Angle1= 1, 2, 3
Angle2= 5, 6
Angle3= 8, 9
Angle4= 11, 12
FlapAngle1= 4, 5
FlapAngle2= 7, 8
FlapAngle3= 10, 11
FlapAngle4= 13, 14
;
; Polynomial fits for angle calibrations
;
Order: 0, 1, 2, 3, 4, 5
;
Angle1Cal= 4.3977, 0.99426, -0.0004268, 0.000010877, 0, 0
Angle2Cal= 5.3510, 0.98482, -0.0008244, -0.000011196, 0, 0
Angle3Cal= 1.4440, 0.99731, 0.0006800, -0.000041889, 0, 0
Angle4Cal= 1.1188, 0.99789, -0.0002240, -0.000011629, 0, 0
FlapAngle1Cal= 4.3569, 1.00410, 0.0001892, -0.000015192, 0, 0
FlapAngle2Cal= 6.0283, 0.99658, -0.0005375, -0.000009915, 0, 0
FlapAngle3Cal= 7.7215, 0.99007, -0.0002878, 0.000022040, 0, 0
FlapAngle4Cal= -5.0332, 1.03268, -0.0025317, 0.000062695, 0, 0
;
; Zeroing values to be subtracted from all angles after corrections
;
ZeroPoint= 0 ; The angles were Zeroed at this point
;
Angle1Off= 0
Angle2Off= 0
Angle3Off= 0
Angle4Off= 0
FlapAngle1Off= 0
FlapAngle2Off= 0
FlapAngle3Off= 0
FlapAngle4Off= 0
Sample Video.dat File  (Numbers only, text in italics added for identification only)

92  
-0.002  Alpha (Angle-of-Attack of Model or Wing) 
0.0000  Alpha2,  
0.0000  DPitch  
0.0000  Pitch2  
4  ID  
0.0000  Roll (Roll angle of Model)  
0.0000  Arcsec  
9.998  Mach (9.998 usually indicates no flow)  
69.5  Total Temperature in Wind tunnel in degrees Fahrenheit  
0.30  Total Pressure in PSI  
9  Q  
542.6  Test number  
902  Run number of test  
03-09-2000  Date of test  
12:20:54  Time point was taken

Sample MDef.send File  (Text in italics added for identification only)

P TEST 0  Test Number  
P RUN 0  Run Number of Test  
P POINT 0  Tab/Point/Sequence Number  
P ALPHA -3  Angle-of-Attack of Model or Wing  
P MACH -3  Wind speed in tunnel  
P TEMP -1  Total temperature (°F)  
P PRESSURE -2  Total pressure (PSI)  
P Q -1  
P ROLL -2  Roll angle of Model or Wing under test  
P HOUR 0  Time point was taken  
P MINUTE 0  
P SECOND 0  
P YEAR 0  Date point was taken  
P MONTH 0  
P DAY 0  
P ID 0  Optional data  
P Alpha2 -3  Optional data  
P DPitch -3  Optional data  
P Pitch2 -3  Optional data  
P Arcsec -3  Optional data  

The file above is only an example of what the Data Acquisition System may require for sending the data to MDef. In this example, the negative numbers represent the number of decimal places for formatting the values to be sent.
The following file samples have too many columns to print properly, the extra columns have been split off and are printed a section at a time; some columns have been dropped. The comment lines have been highlighted for readability.

Sample Tunnel.log File

```
% Test  Run  Point Ext --Date-- --Time--  TTemp  TPres  Mach
542  902     90     2000 03 09 11 19 43   67.7    0.30  9.998
542  902     91     2000 03 09 12 11 02   69.1    0.30  9.998
542  902   +91.001 2000 03 09 12 12 18   69.3    0.30  9.998
542  902   +91.002 2000 03 09 12 12 30   69.3    0.30  9.998
542  902   +91.003 2000 03 09 12 12 40   69.3    0.30  9.998
542  903     92     2000 03 09 12 20 54   69.5    0.30  9.998
```

```
Qinfft  Alpha TwistSLI TwistSLO TwistSRI    ID     Roll TwistSRO
999.9  -0.085  542.000  903.000   90.000    13     0.47  9.998
999.9  -0.002  542.000  903.000   91.000     4     0.00  9.998
999.9  -0.002  542.000  903.000   91.000     4     0.00  9.998
999.9  -0.001  542.000  903.000   91.000     4     0.00  9.998
999.9  -0.002  542.000  903.000   92.000     4     0.00  9.998
```

Sample Log.dat File

```
% Test  Run  Point Ext --Date-- --Time-- xdim xpos ydim ypos
542  902     90     2000 03 09 11 19 43   752    0  240    0
542  902     91     2000 03 09 12 11 02   752    0  240    0
542  903   +91.001 2000 03 09 12 12 18   752    0  240    0
542  903   +91.002 2000 03 09 12 12 30   752    0  240    0
542  903   +91.003 2000 03 09 12 12 40   752    0  240    0
542  903     92     2000 03 09 12 20 54   752    0  240    0
```

```
camvpix   camhpix     xp_pixel    yp_pixel     xs_pixel
0.0259970  0.0109970  370.0000000 108.0000000  374.3000000
0.0259970  0.0109970  370.0000000 108.0000000  374.3000000
0.0259970  0.0109970  370.0000000 108.0000000  374.3000000
0.0259970  0.0109970  370.0000000 108.0000000  374.3000000
0.0259970  0.0109970  370.0000000 108.0000000  374.3000000
```

```
ys_pixel      kl sh_rat   xshift yshift de_x de_y      c
107.6000000 -0.0011 1.0000   0.0000 0.0000    1    1  12.90
107.6000000 -0.0011 1.0000   0.0000 0.0000    1    1  12.90
```

21
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<th>omega</th>
<th>phi</th>
<th>kappa</th>
<th>Xc</th>
<th>Yc</th>
<th>Zc</th>
<th>wonb</th>
<th>minm</th>
<th>maxm</th>
</tr>
</thead>
<tbody>
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<td>-151.4449</td>
<td>-3.0797</td>
<td>-83.9444</td>
<td>-1.63</td>
<td>80.25</td>
<td>-86.09</td>
<td>1</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>-151.4449</td>
<td>-3.0797</td>
<td>-83.9444</td>
<td>-1.63</td>
<td>80.25</td>
<td>-86.09</td>
<td>1</td>
<td>12</td>
<td>4</td>
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<td>5</td>
<td>5</td>
<td>3</td>
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<td>3</td>
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<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
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<td>2.0</td>
<td>3</td>
<td>0.406</td>
<td>0.000</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1.00</td>
<td>2.0</td>
<td>3</td>
<td>0.406</td>
<td>0.000</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
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<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
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**Sample Centxxxxx File**

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7 122.021 109.201 102.818 153.238 83.817 211.050 319.076 
13 122.018 109.211 102.780 153.242 83.819 211.058 319.070 
. 
49 122.014 109.209 102.811 153.228 83.819 211.062 319.041 
55 122.019 109.214 102.798 153.241 83.814 211.059 319.076 
% 
159.382 304.557 201.709 294.208 230.292 394.056 118.416 
159.377 304.567 201.706 294.210 230.292 394.050 118.427 
159.382 304.541 201.691 294.210 230.301 394.068 118.425 
. 
159.370 304.558 201.707 294.199 230.284 394.059 118.420 
159.380 304.554 201.702 294.221 230.293 394.076 118.429 
% 
377.663 163.299 359.569 228.071 510.581 59.691 495.904 
377.672 163.308 359.564 228.069 510.583 59.696 495.914 
377.672 163.308 359.556 228.073 510.578 59.696 495.908 
. 
377.664 163.310 359.586 228.065 510.579 59.695 495.896 
377.673 163.306 359.596 228.070 510.582 59.696 495.904 
% 
100.631 472.642 189.700 566.210 127.815 555.970 186.196 
100.623 472.621 189.712 566.188 127.812 556.011 186.193 
100.621 472.638 189.706 566.202 127.816 555.996 186.186 
. 
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Sample Cerrxxxx File

*(The plus signs in front of the field numbers indicate that the sample was manually triggered)*

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+25  153.766 159.821   134.679 212.534   383.722  34.327   360.517
+265 153.765 159.815   134.656 212.532   383.716  34.327   360.539
+277 153.777 159.818   134.647 212.522   383.710  34.323   360.526
+289 153.771 159.811   134.669 212.549   383.715  34.322   360.523

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  85.560   241.561 108.913   444.779 119.850   218.521 165.099

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  85.558   241.573 108.915   444.761 119.857   218.508 165.092

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  432.755 194.979   329.549 199.112
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  432.735 194.979   329.575 199.120
  432.738 194.986   329.550 199.122
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The last seventeen columns of this file (---Date--- through Arcsec) can also be found in Tunnel.log.
# Videogrammetric Model Deformation Measurement Software Package

## Reference Manual for MDef.exe

### Title and Subtitle

Videogrammetric Model Deformation Measurement Software Package

### Authors

Kenneth H. Cate

### Performing Organization Name(s) and Address(es)

NASA Langley Research Center
Hampton, VA 23681-2199

### Abstract

The program MDef.exe was created to take images in wind tunnels of models under test, identify targets, compute the target's centroids, compute the target's real-world X-Y-Z coordinates and the model's deformation (vertical displacement and wing twist).