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2D Realtime 2.1.X Manual

Revision 1.4

For use with:

SPEC 2D-S, 3V-CPI (2D-S), Hawkeye 2D-S, HVPS, and 2D-128 probes.

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SPEC Inc.
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Contents

Overview

The 2D Realtime version 2 has been substantially updated and optimized for efficient use in challenging field environments. The same program is now used for data acquisition on a variety of SPEC Inc. optical array probes, including the 2D-S, 3V-CPI (2D-S), Hawkeye 2D-S, HVPS, and the 2D-128. The program is written entirely in Microsoft Visual Studio 2010 C++, and uses OpenGL for image and plot displays. This makes optimal use of a video card, if available, to minimize CPU load while providing fast displays of the incoming data.

The real time plots can quickly and easily be saved with the push of a button at any time during acquisition or playback. The program supports a basic "preview playback," in which a recorded data file can be opened to browse through the images and housekeeping data, useful for laboratory testing. Data processing, however, is being moved into an entirely separate IDL program.

Installation of the Realtime program has been simplified to a single self-extracting executable, available on SPEC's webpage: **`http://www.specinc.com/downloads`**. All program configurations are automatically stored in a single ini configuration file; there is no use of the Windows Registry to store program settings. Advanced features such as Autostart, Laser Power Control, and UDP Outputs are detailed below in the Advanced Settings section (p. 13).

Basic Operation

The 2D Realtime 2.X program performs data acquisition for a variety of SPEC Inc. probes. There are two main modes of operation:

- **Monitor** mode is initiated by clicking the button containing a black triangle icon, located in the upper left of the Realtime screen (see **Figure 1**). Monitor mode connects to the probe and "monitors" the probe, displaying realtime images of objects that pass through the sample volume, as well as instrument housekeeping data. In Monitor mode, data files are NOT recorded. This mode is useful for probe testing and laser alignment.

- **Record** Mode (button at the upper left of the GUI containing a red triangle icon) is used to record data from the probe. This is the main operational mode of the software.

To stop Monitoring or Recording, use the **Stop** button (red circle with white X at upper left of the GUI). This action will close the data files that are being written to and disconnect from the probe.

After initiating Monitor or Record, the **Housekeeping Count** (HKs) will increment at 1Hz, which indicates a good connection to the probe. When the connection is verified by checking that the housekeeping count is incrementing, click the "**Send Command Packet**" button to initialize the probe heater and laser settings. Operation with an external True Air Speed source will automatically initialize the True Air Speed (TAS). For bench operation without an external True Air Speed source, the TAS should be set by entering the appropriate TAS value in the True Air Speed box and clicking the adjacent "**Send New True Air Speed**" button. The TAS currently in use by the probe is reported in the HK TAS field.

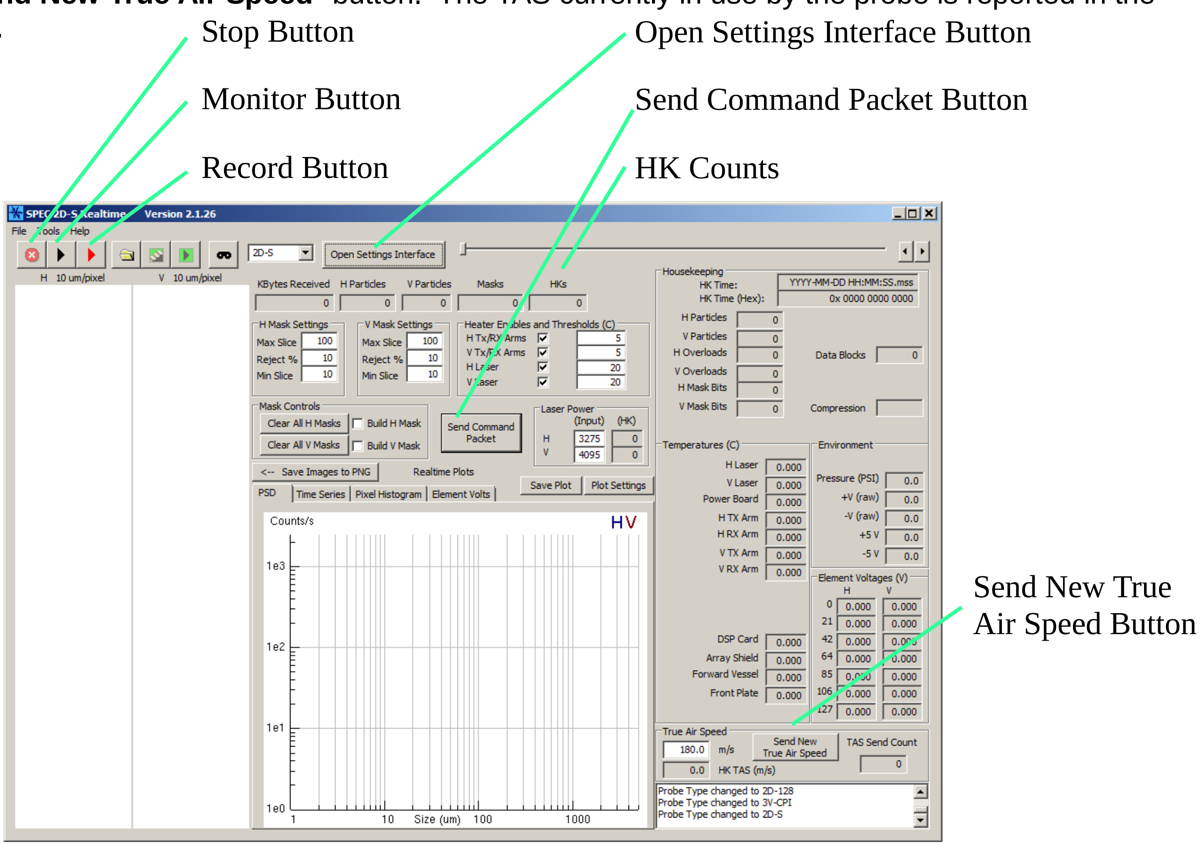


Figure 1. Screenshot of 2D Realtime 2.X GUI showing buttons for basic operation.

Recorded Data is stored in a fixed output directory. The probe type determines the specific directory name beyond <base directory>\data_<probe type>, for example all 2D-S data is stored in:

`C:\SPEC\Realtime2DSGUI\data_2D-S\.`

Configuration files, log files, this manual, and saved plots are also stored under subdirectories in:

`C:\SPEC\Realtime2DSGUI\`

GUI Layout

The 2D Realtime 2.X Graphical User Interface has a fixed layout for the major controls and displays. Major GUI components are highlighted in **Figure 2**.

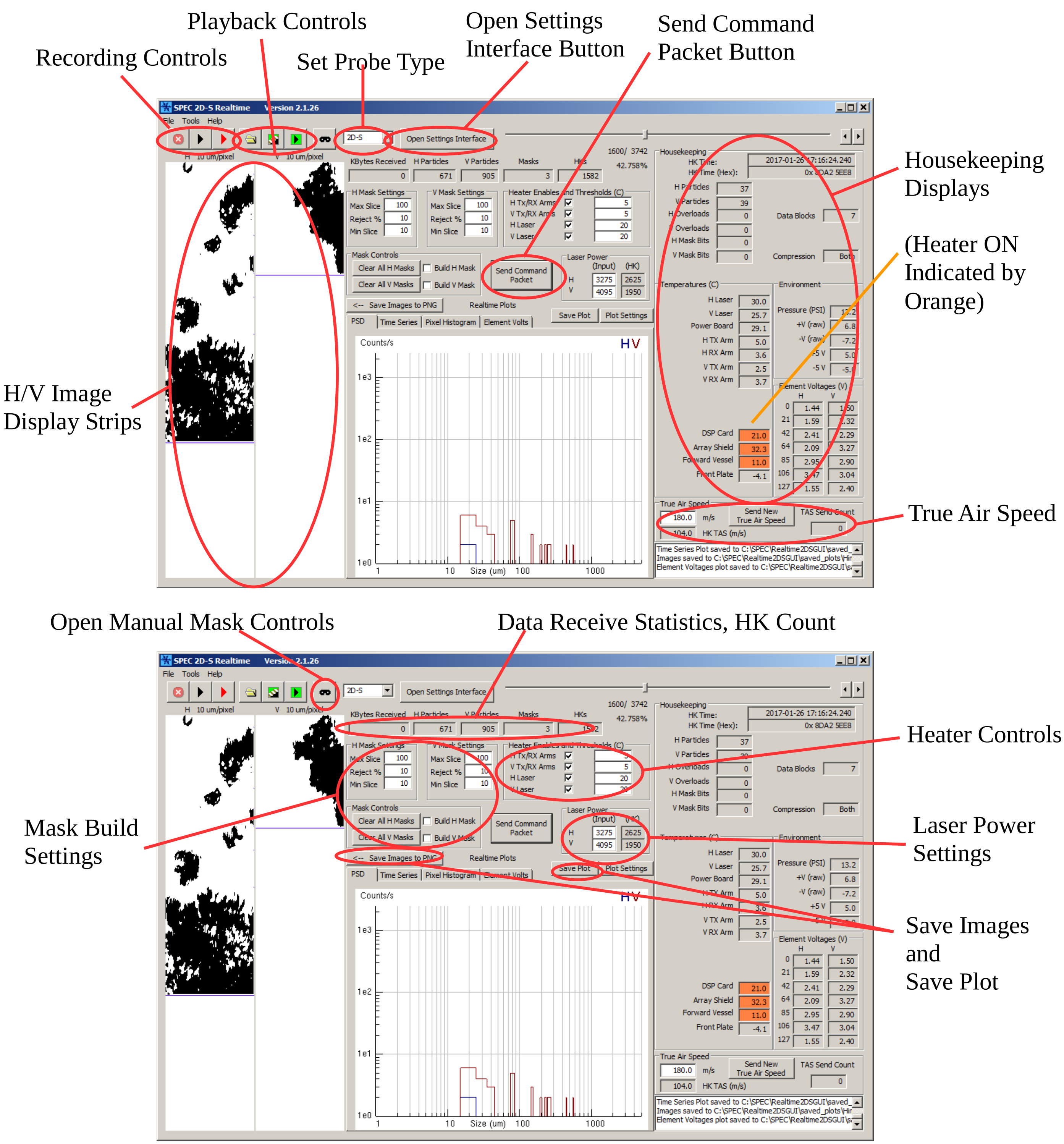
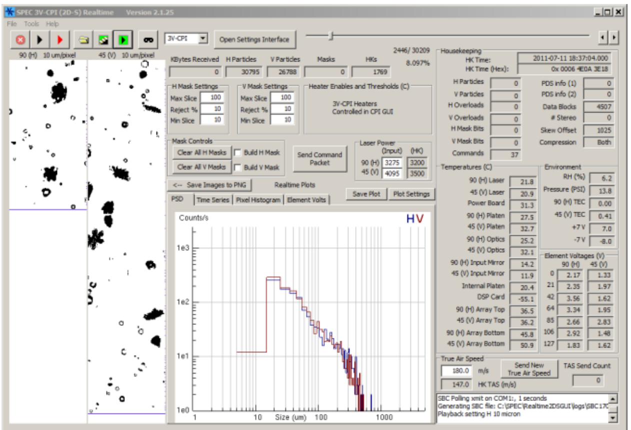


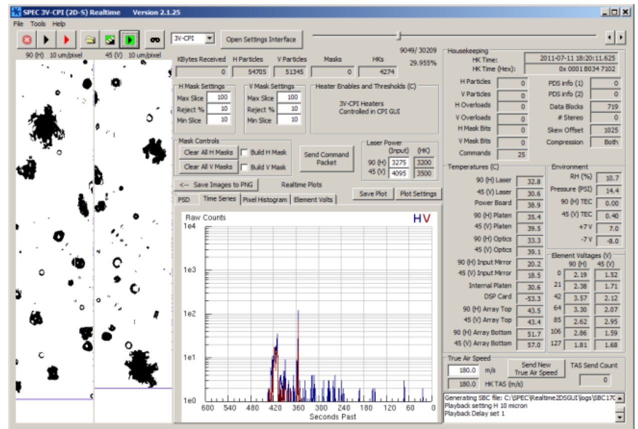
Figure 2. Major components of the 2D Realtime 2.X GUI

There are four plots on a tabbed interface which update during acquisition and playback, as shown in the examples in **Figure 3**. The user can view any one of these plots at a time, selected by clicking on the appropriate tab above the plotting window. At any time, pressing the "**Save Plot**" button will save the current plot to a png file. The filename is automatically generated with the current UTC time, and saved to the directory:

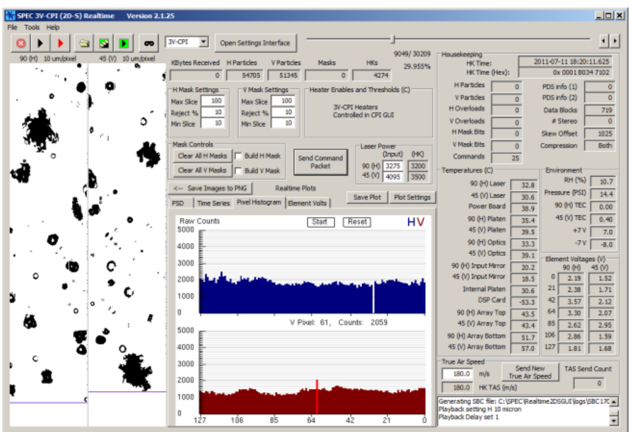
`C:\SPEC\Realtime2DSGUI\saved_plots\`



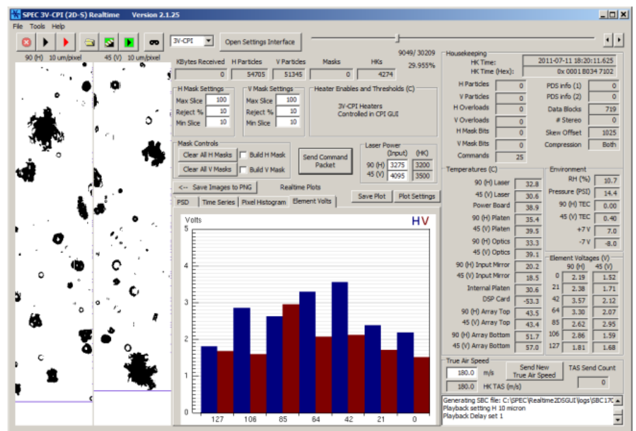
Raw Counts Particle Size Distribution (PSD)



Raw Counts Time Series Plot



Pixel Histogram



Element Voltages

Figure 3. Four plots available in the GUI from the tab interface above the plotting window. For these plots, the H channel is represented in blue, and the V channel in red.

The four plots include:

- The **Counts PSD** shows a size distribution of the raw counts in each bin for each channel, for all images acquired in each second. The sizing is based on the number of slices in the TAS direction.

- The **Counts Time Series** shows a time series of the total raw counts observed in each channel for the past 600 seconds (ten minutes of history).

- The **Pixel Histogram** is a mouse interactive plot. The count accumulator is started with the *Start* button in the plot. The Start button turns into a *Pause* button, which halts the count accumulation. The *Reset* button clears the counts. Clicking on the plot *highlights* the current pixel and displays the pixel number and count. In the above plot, V Pixel 61 has been clicked, and it is at 2059 counts. This pixel is slightly noisy. H pixel 29 was dead on this probe at time of acquisition, thus the white gap in the H histogram.

- The **Element Voltages** plot is a simple visual representation of the analog element voltages. Seven photodiodes per channel are recorded by analog to digital voltage converters. This plot shows a rough representation of the beam shape. It is useful for laser alignment, and checking the cleanliness of the windows. It is recommended to save the Element Voltages plot before attempting a cleaning, for a direct before/after cleaning comparison. Please note the laser power level impacts the element voltages, so comparisons should be performed at the same laser power level.

Additional program settings are located in a separate tabbed dialog, opened by the "**Open Settings Interface**" button (see **Figure 2**), or via the top menu bar. The settings dialog interface window can be closed at any time. The settings are immediately saved to the ini file upon changes. Please see the next section, "General Settings", for further details.

The **H/V Mask Settings** and the **Mask Controls** on the main GUI are used to control building the probe masks. When Send Command Packet is pressed, if the Build H/V Mask checkboxes are checked, the probe will use the settings as parameters to determine if any pixels should be masked. This should only be done out of cloud in clear air. Taking a mask in cloud can result in many or all pixels being masked, which will result in loss of data. The operator can quickly clear the masks using the **Clear All H/V Masks** buttons. To use Send Command Packet while in cloud and avoid taking a mask, uncheck the Build H/V Mask checkboxes. The standard Mask Settings work consistently well in the field, however, they can be changed to accommodate an extraordinary situation, such as a dirty window or noisy photodiode. The standard Mask Settings are:

Max Slice	100
Reject %	10
Min Slice	10

During acquisition, the program has a layer of protection against being closed accidentally. Any close event brings up the warning dialogue in **Figure 4** -- the program is still acquiring data. Pressing OK will confirm closing the program. Pressing Cancel will continue normal operation uninterrupted.

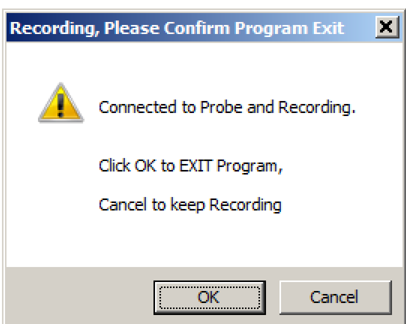


Figure 4. Warning dialogue to protect against accidental closure of the GUI during data acquisition.

Settings

Changing the Probe Type

The 2D Realtime GUI supports data acquisition from a variety of SPEC probes. As of version 2.1.26 these include 2D-S, 3V-CPI (2D-S), Hawkeye 2D-S, HVPS, and 2D-128. The **Probe Type** is changed via a drop down list in the upper left middle of the main GUI (see **Figure 5**). Probe type cannot be changed when in Monitoring, Recording, or Playback modes -- the control is disabled to prevent operational errors.

The HVPS and 2D-128 are single channel probes, with only one array and one illumination laser. The single channel is considered a V (Vertical) channel for display and processing. The 2D-S, 3V-CPI (2D-S), and Hawkeye 2D-S are all dual channel probes, with both H (Horizontal) and V (Vertical) channels. The 3V-CPI (2D-S) and Hawkeye 2D-S have an updated Digital Signal Processor, which uses a 48 bit timestamp. These probes also generate separate data and housekeeping files, as opposed to the 2D-S, HVPS, and 2D-128, which generate a single file containing both data and housekeeping information, and use a 32 bit timestamp.

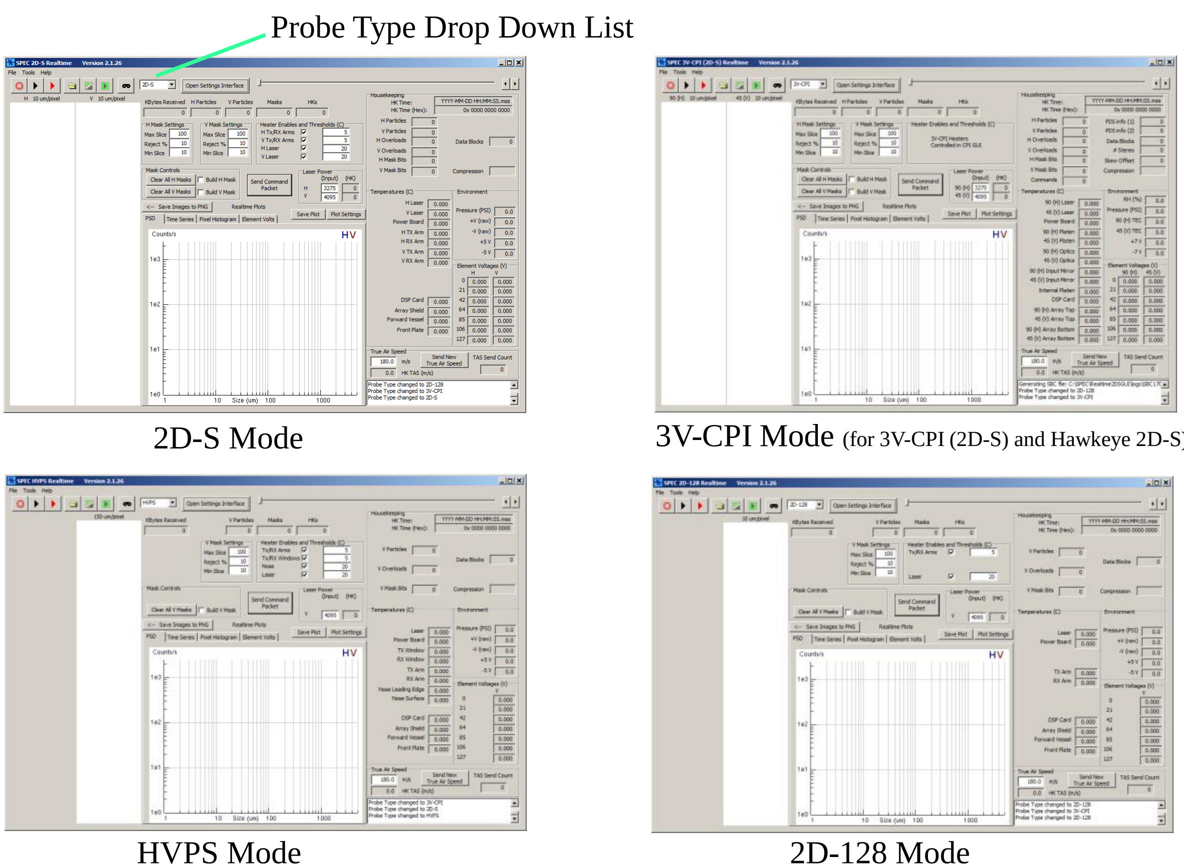


Figure 5. 2D Realtime GUI configuration for the various optical array probe types.

The Probe Type setting in the GUI *MUST* be set to the correct probe type, or the probe will not operate properly and data may be impossible to process. The heater and laser controls, as well as the interpretation of housekeeping data, are all dependent on the probe type. When the Probe Type is selected, the GUI layout is updated automatically to display relevant data and expose the appropriate heater controls. The H and V Image Strips display the pixel resolution of each channel at the top of each strip. Note that the Hawkeye H 50 micron resolution channel is detected automatically from a flag in the housekeeping data.

Setting the Probe IP Address

The Probe IP and Data System IP addresses must be specified in the **IP Address** tab of the Settings Interface Window, shown in **Figure 6**. The default ports are 2000 and 2002 for HK -- these should *NOT* be changed by the user, and are provided for development and testing only.

The **Ping Probe IP** button is functional on WinXP; however, as of version 2.1.26, it is not functional on Windows 7. This feature will be available in future releases.

The **Ping Subnet** button is a debugging tool for examining the network by pinging all 254 addresses on the 255.255.255.0 subnet, based on the specified Data System IP. The responses, or lack thereof, are printed in the adjacent window. This functionality was developed as a field tool for a dynamic flight environment where probes were being exchanged rapidly for variations in payload configuration. As of version 2.1.26, this button is similarly not functional on Windows 7. This feature will be available in future releases.

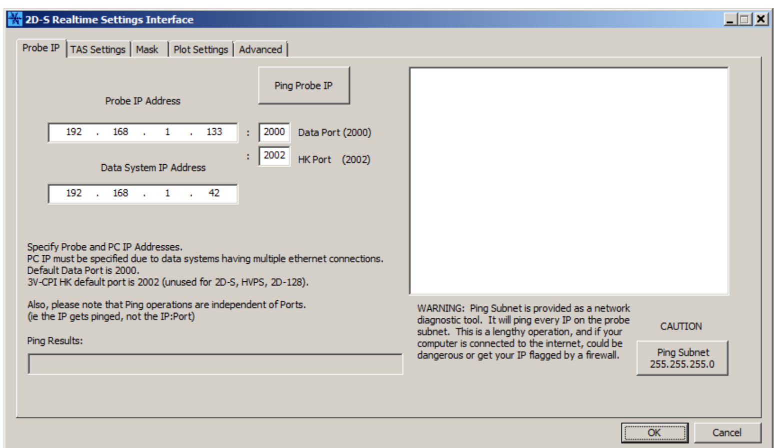


Figure 6. Probe and Data System IP Address tab of the Settings Interface Window.

Setting the External True Air Speed (TAS)

The True Air Speed (TAS) is sent to the probe in realtime and is used to adjust the pixel clock speed in order to maintain correct image acquisition. An incorrect TAS will result in image oversampling or undersampling (elongated or squished images). There are 3 potential TAS Sources:

1) **FIXED SETTING** — The TAS is set to a fixed value via the True Air Speed controls on the main screen of the GUI (see **Figure 2**).

2) **Serial Input** — The TAS is updated via a serial input string provided from the aircraft. Set the COM Port, Baud Rate, and Token (string) Position to match the input TAS string in the TAS tab of the Settings Interface Window shown in **Figure 7**. Use the Test TAS Input checkbox to verify.

3) **UDP Input** — The TAS is updated via a UDP packet received over an Ethernet port. Specify the UDP Listen Port and Token (string) Position in the TAS tab of the Settings Interface Window shown in **Figure 7** to match the input TAS string.

The input TAS units can be in meters/second (m/s) or knots. TAS is always converted to m/s for display and for sending to the probe. The TAS Header is used to filter other potential UDP or Serial packets not intended for this program.

The TAS limits and percent change are additional filters on the input string. The limits prevent nonphysical values from being sent to the probe. The percent change helps to prevent thrashing of the pixel clock rate for minor changes in the TAS.

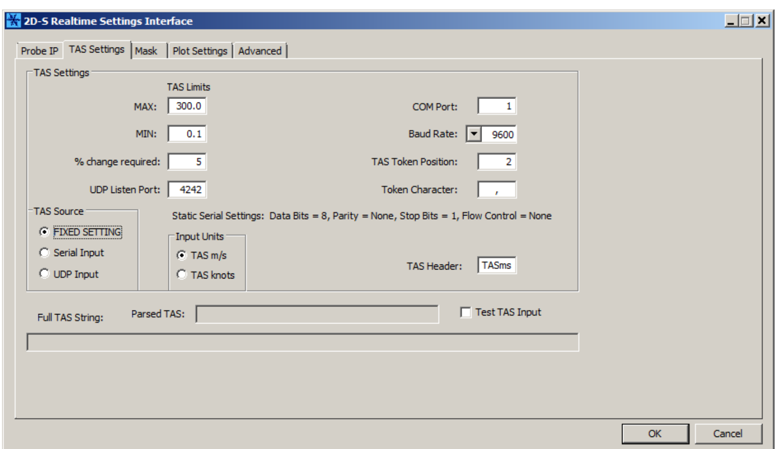


Figure 7. TAS Settings tab of the Settings Interface Window.

Manual Mask Configuration

The **Mask Configuration** tab, shown in **Figure 8**, allows detailed viewing of the current mask, as well as complete control over the mask on a bit by bit basis. Normal operation should use the standard automatic mask generation (with the Build H/V Mask checkboxes on the main GUI). Manual Mask setting is an advanced topic that is useful for a problematic flight or laboratory testing.

The orange graphics represent a hardware mask of 0 (zero = masked), while white graphics represent a mask of 1 (one = not masked). Masking out a noisy bit can greatly reduce data file size and processing time, and can allow more particle data to be usable. Generally, a maximum of 1-3 masked bits per channel is acceptable -- more than this indicates that the probe needs to have the windows cleaned, purged for moisture, or the lasers realigned (see Troubleshooting).

The current mask received from the probe is also displayed in the H/V image strips. This allows the user to immediately see the current mask from the main GUI. If an image strip suddenly turns all orange, this indicates a full mask on that channel, and thus that no images are being recorded. Please see Mask Controls under Basic Operation, and Troubleshooting.

The figure shows two contrived mask examples under the "New" mask fields. These are entered by the user by changing the hexadecimal values in the white text boxes. The "Current" mask fields in the figure are showing white graphics, indicating no masked bits. Correspondingly, the Current mask text fields are showing all hexadecimal FFFF's, a representation of all 1's. There is a hexadecimal and binary conversion chart provided for convenience. The text input fields restrict the input to the hex characters [0-9A-F], and lower case character inputs are automatically upgraded to upper case values (i.e. a->A and e->E). Mouse clicking in the mask graphic shows the pixel number, 0 to 127, which is useful for making a manual mask and comparing to the Pixel Histogram.

The probes have 128 photodiodes per channel, which are interpreted as 128 bits of an image. Each hex value represents 4 bits. For masking, each channel is represented as 8 groups of 4 hex values, totaling 128 bits per channel. New manual masks can be generated by typing new values into the New hexadecimal input fields. There are shortcut buttons to force populate these fields with all 1's (not masked), all 0's (masked), and to restore the current mask. Once a mask is specified, use the "Send New" button to send the mask to the probe. As an example, in **Figure 7**, the new H mask has the left 64 bits of the array completely masked out, as well as the edge pixel on the 0 (right) edge. The new V mask has pixel 127 masked out, and a demonstration of each hex value [0-9A-F].

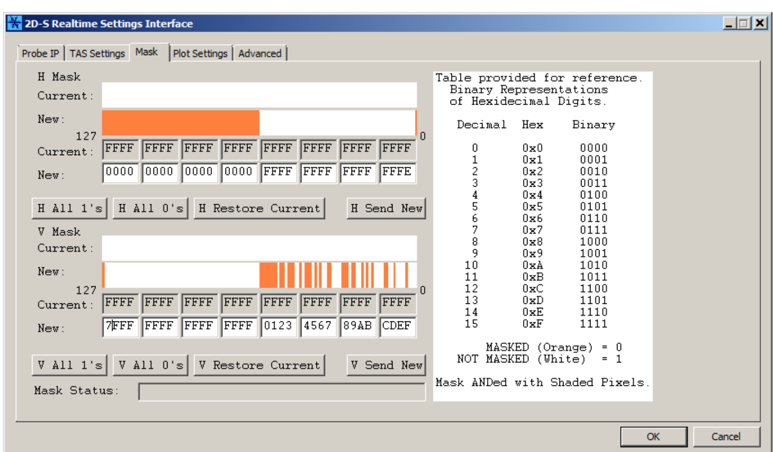


Figure 8. Mask Configuration tab of Settings Interface Window.

Advanced Settings

The **Advanced Settings** tab of the Settings Interface Window, shown in **Figure 9**, contains settings for Automatic Laser Power Control, Automatic Startup, UDP Data Broadcast, Periodic Mask Generation and Auto Full Mask at Low Power. There are also **Compression Mode** and **Spare** inputs, however these should never be changed by the user and are included for engineering and development only. Compression Mode should be set to Both. The Spares affect the PID heater coefficients, and should be set as in **Figure 9** below. The user-adjustable advanced settings include:

- **Laser Power Control** adjusts the H and V laser power settings in order to maintain optimal element voltages throughout a flight. During normal use, laser power control should be enabled, with the settings as in **Figure 9**. The control can be disabled for lab testing and laser alignment.

- **Periodic Mask Generation** will attempt to take new masks in clear air, and avoid taking masks in clouds.

- **Auto Full Mask at Low Power** can help prevent generation of extremely large data files in the event of extreme fogging or laser power overheat shutdown.

- **Automatic Start** will start data recording after the number of seconds specified in Startup Delay has passed following startup of the GUI. The startup countdown appears in the title bar of the main GUI, and can be canceled by unchecking the box during countdown. For flights with an operator, it is generally best practice to manually start the probe at an appropriate time during taxi. This helps prevent laser overheat when operating in hot environments, as well as collection of un-useful data while sitting on the runway.

- **Universal Datagram Protocol (UDP)** outputs can be enabled to transmit probe housekeeping and even full Particle Size Distribution (PSD) data over the Ethernet to the specified IP address and port. This is used for remote monitoring of probe health during autonomous operation, as well as for transmission of data and probe health information via satellite or radio transmissions.

Periodic Mask Generation, Auto Full Mask at Low Power, and Automatic Start are features designed for autonomous probe operation, such as unsupervised flights on the WB-57 or Global Hawk**.**

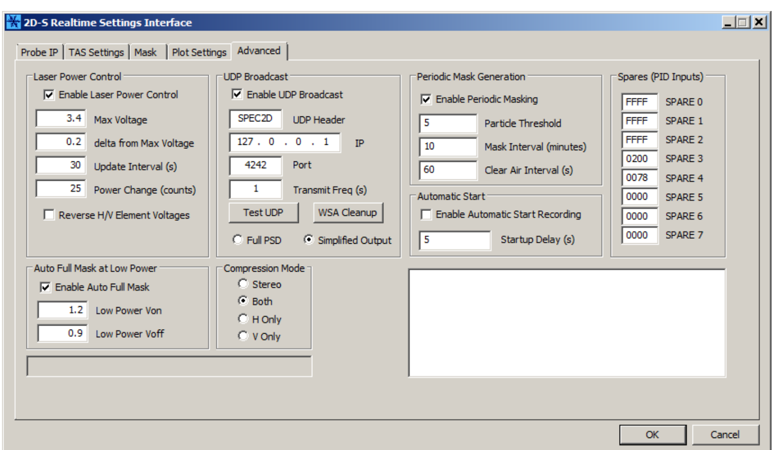


Figure 9. Advanced Settings tab of Settings Interface Window.

Preview Playback

Data files generated by the 2D Realtime 2.1.X can be opened by the program and played back. The images and housekeeping will be displayed, and the various plots will be (re)generated and displayed. The rate of playback is adjustable, and the user is able to use the slider to adjust the file position to skip ahead or replay any part of the data file, as highlighted in **Figure 10**.

Please note that the probe mode setting must match the type of file being played back -- the File Open dialog file extension filter is set based on the probe type. The playback slider is more responsive/easier to move when the Playback is Paused. Also note that the displayed HK times are inaccurate as of version 2.1.26, which should be corrected in a later version.

Playback is also a good opportunity to use the Pixel Histogram to help detect noisy or dead pixels. While the Pixel Histogram can be enabled during data acquisition (Monitor or Record), the overhead of the calculations may cause lower-end computers to bog down and not acquire all data. Thus, it is highly recommended not to enable the Pixel Histogram accumulator during Recording of data.

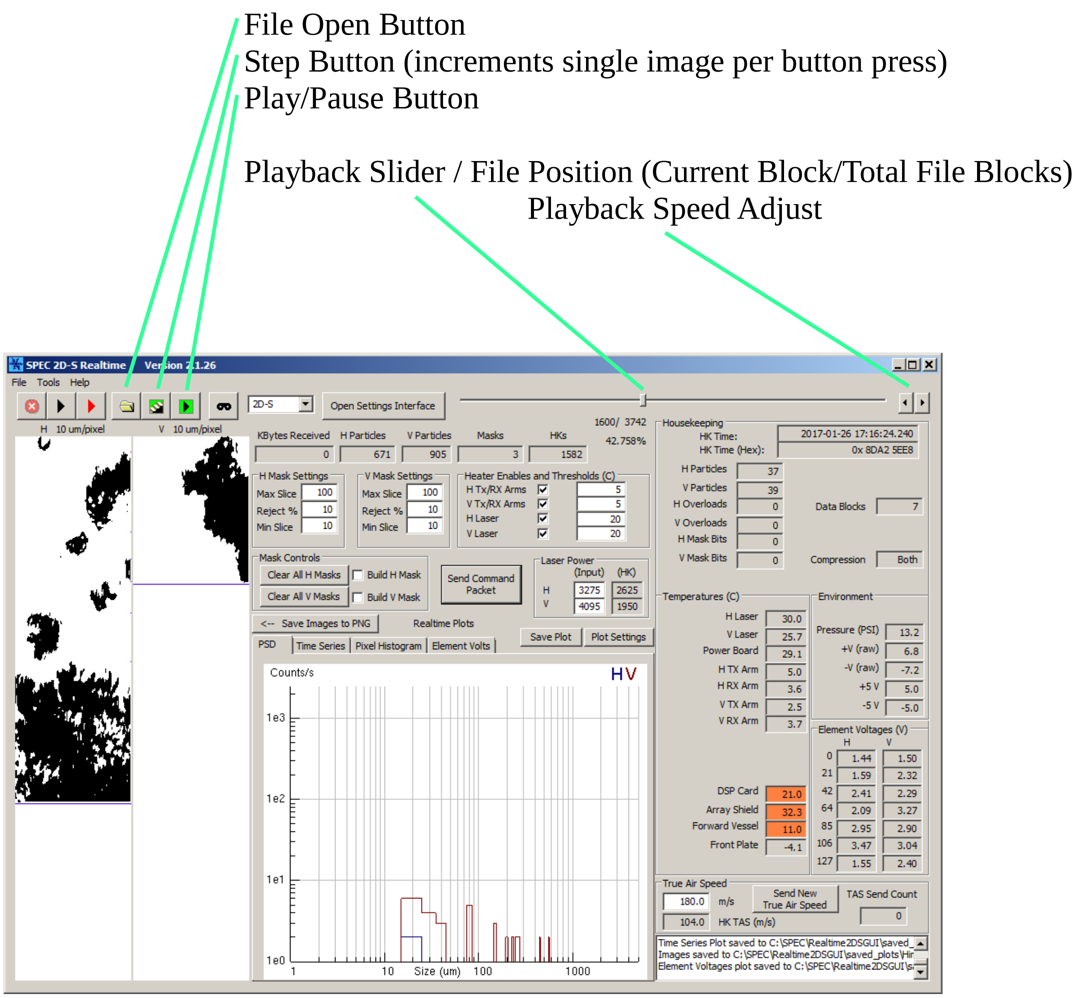


Figure 10. Screenshot of 2D Realtime 2.X GUI highlighting relevant buttons for data file playback.

Installation and Setup

The 2D Realtime 2.X self-extracting executable is available for download on the SPEC Inc. website: http://www.specinc.com/downloads.

The program was developed on Windows 7, and has been extensively tested on WinXP 32 and 64 bit, as well as Windows 7 32 and 64 bit. There has been limited testing on Windows 8 and 10, though the program appears to run correctly on these platforms.

All links to "Realtime GUI" under each probe type section are links to the identical installation file. The different links and filenames are due to a limitation in the table implementation on the website.

To **install** the SPEC 2D Realtime 2.X:

1) Run the self-extracting executable installation file (install_SPEC_Realtime2DSGUI_v2.1.26.exe) -- you must have administrator privileges on the machine to install.

2) Select "Yes" on the User Account Control warning to allow the program to install.

3) You will be greeted with a standard Installation Wizard. Continue clicking Next and finally Install. You have a choice of the installation directory and whether to make a desktop icon -- the defaults should be generally acceptable.

4) If you have a previous installation, the realtime2ds.ini file will be backed up automatically. You will be prompted to choose the ini file from the new installation or keep your existing ini file. If you choose "Yes" to overwrite, you will likely need to reconfigure the probe IP address and other settings before the probe can be used.

The default program installation directory is:
`C:\Program Files (x86)\SPEC\Realtime2DSGUI\.`

However, the user should never need to access these files. The main executable name is "Realtime2DSGUI.exe." The desktop icon and start menu icon are shortcuts to this executable.

To **run** the program, use the desktop icon, or Start -> (All Programs) -> SPEC Realtime 2D-S GUI -> SPEC Realtime 2D-S GUI. The default installation also adds a shortcut to the CPU Startup, so that the program will run immediately after windows loads.

The Probe and Data System IP Addresses must be set correctly for the Ethernet connection to the probe. The reason the Data System IP Address must be specified is to simplify the connection logic on a Data System with multiple Ethernet connections, which is a standard feature for flight Data Acquisition Systems (other connections might include an NTP network or another Ethernet probe like an FCDP, Hawkeye FCDP, or FSSP).

Troubleshooting Tips

Ensure the Probe Type is set correctly in the GUI for your probe (see Changing the Probe Type)

All masked bits?

Signs/Symptoms:
Orange display in H and/or V image strip, Mask Bits housekeeping displaying 128, Mask Settings showing all zeros in current mask and displaying orange graphics.

Causes:
Taking a mask in cloud, low laser power, internal condensation, laser overheat protection, laser beam path blocked (internally or externally).

Troubleshooting:
- Try clicking "Clear All H/V Masks" button.
- Check laser power setting is a value in the range 0-4095.
- Check laser temperature -- over 45 ^{o}C will trigger hardware laser overheat protection. If overheated, allow laser to cool -- this can be expedited by powering down the probe.
- Check Element Voltages (3.4 V generally optimal), look at Element Volts plot.
- Check H/V Mask Settings (default Max Slice 100, Reject % 10, Min Slice 10).

Probe not connecting?

Signs/Symptoms:
No images or Housekeeping, no KBytes received or no HK packets.

Causes:
Bad Ethernet connection, incorrect Probe or Data System IP address, no probe power.

Troubleshooting:
- Check physical connection (probe power and Ethernet connections).
- Check that the probe has power, are the lasers visible? (Can be hard to verify under high ambient light).
- Check network connectivity under Windows Networks, Open Network and Sharing Center, check Data System IP address, and if the network connection is active.
- Check Probe IP Settings and Data System IP Setting in the Probe IP GUI -- make sure they match the specified Probe IP and currently set PC IP address -- ports should always be 2000 (Data Port) and 2002 (HK Port).
- Try pinging the probe (Start -> Run -> cmd, then ping 192.168.1.133 or correct probe IP).
- Is a firewall blocking access?

True Air Speed issues

Signs/Symptoms:
TAS not updating, TAS varying wildly, images extremely squished (undersampled) or elongated images (oversampled).

Causes:
TAS input not setup correctly, TAS input string being misparsed, TAS Source not outputting string or not connected

Troubleshooting:

- Check TAS Settings for Serial or UDP input. Check port settings, TAS Token Position (which field the TAS is in), TAS input units (m/s vs knots), Token/separator character, Header.
- Use the Test TAS Input checkbox to preview the unparsed and parsed TAS string.
- Check that the external TAS source is transmitting and the wires connected properly.
- If unable to read in, then set the TAS Source to FIXED SETTING, and manually update the TAS to within about 10% of the actual airspeed value.