AFRL-HE-AZ-SR-2002-0005

UNITED STATES AIR FORCE RESEARCH LABORATORY

IMAGE GENERATOR REQUIREMENTS FOR DRIVING THE 5120 x 4096 PIXEL ULTRA HIGH-RESOLUTION LASER PROJECTOR

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Approved for public release; distribution is unlimited.

March 2003

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)
01-03-2003

2. REPORT TYPE
Final

3. DATES COVERED (FROM - TO)
xx-01-2001 to xx-08-2002

4. TITLE AND SUBTITLE
Image Generator Requirements for Driving the 5120 x 4096 Pixel Ultra High-Resolution Laser Projector
Unclassified

5a. CONTRACT NUMBER
F41624-97-C-5000

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
62205F

6. AUTHOR(S)
Surber, Ben L ; Author
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5d. PROJECT NUMBER
1123

5e. TASK NUMBER
B0

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME AND ADDRESS
L-3 Communications
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS
Air Force Research Laboratory
Human Effectiveness Directorate
6030 South Kent Street
Mesa, AZ85212-6061

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL; AFRL/HEA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-HE-AZ-SR-2002-0005

12. DISTRIBUTION/AVAILABILITY STATEMENT
APUBLIC RELEASE
,

13. SUPPLEMENTARY NOTES
Air Force Research Laboratory Technical Monitor: Mr Philipp W. Peppler, AFRL/HEAE, (480) 988-6561, X-273, DSN 474-6273.

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16. SECURITY CLASSIFICATION OF:

a. REPORT	b. ABSTRACT	c. THIS PAGE
Unclassified	Unclassified	Unclassified

17. LIMITATION OF ABSTRACT
Same as Report (SAR)

18. NUMBER OF PAGES
15

19. NAME OF RESPONSIBLE PERSON
Casey, Liz
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19b. TELEPHONE NUMBER
International Area Code
Area Code Telephone Number
480988-6561
DSN
474-6188

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39.18

NOTICES

This special report has been reviewed and is approved for publication.

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http://stinet.dtic.mil

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*: March 2003

2. REPORT TYPE: Final

3. DATES COVERED *(From - To)*: January 2001 to August 2002

4. TITLE AND SUBTITLE

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5a. CONTRACT NUMBER: F41624-97-C-5000

5b. GRANT NUMBER:

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5d. PROJECT NUMBER: 1123

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5f. WORK UNIT NUMBER: 01

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9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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10. SPONSOR/MONITOR'S ACRONYM(S): AFRL; AFRL/HEA

11. SPONSOR/MONITOR'S REPORT NUMBER(S): AFRL-HE-AZ-SR-2002-0005

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Air Force fighter pilots require eye-limited resolution for many simulator training scenarios and tasks. However, the field-of-view, brightness, and contrast of practically every visual system available today is far less than what the pilot sees looking out of the real aircraft. Because of this, current visual systems do not provide a pilot with adequate or eye-limited visual definition. To provide eye-limited or 20/20 visual acuity in a Boeing-St. Louis Visual Integrated Display System (VIDS) and the Air Force's Mobile Modular Display for Advanced Research and Training (M2DART), an ultra high-resolution projector capable of displaying an unprecedented resolution of 5,120 pixels by 4,096 lines at 60 Hz frame rate is required. The Air Force Research Laboratory, in cooperation with Evans & Sutherland Incorporated, is developing a laser projector based upon the Silicon Light Machines grating light valve to meet this order-of-magnitude performance increase over current technology. This document describes the image generator interface, features, and capabilities required to provide imagery to this new class of projector.

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16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Ms Liz Casey
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED	15	19b. TELEPHONE NUMBER *(include area code)* 480.988.6561 x- 188 DSN 474-6188

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EXECUTIVE SUMMARY

Air Force fighter pilots require eye-limited resolution for many simulator training scenarios and tasks. However, the field-of-view, brightness, and contrast of practically every visual system available today is far less than what the pilot sees looking out of the real aircraft. Because of this, current visual systems do not provide a pilot with adequate or eye-limited visual definition. To provide eye-limited or 20/20 visual acuity in a Boeing-St. Louis Visual Integrated Display System (VIDS) and the Air Force's Mobile Modular Display for Advanced Research and Training (M2DART), an ultra high-resolution (UHR) projector capable of displaying an unprecedented resolution of 5,120 pixels by 4,096 lines at 60 Hz frame rate is required. The Air Force Research Laboratory (AFRL), in cooperation with Evans & Sutherland Incorporated (E&S), is developing a laser projector based upon the Silicon Light Machines grating light valve to meet this order-of-magnitude performance increase over current technology.

This document describes the architectural design concepts and defines the requirements for driving the AFRL ultra high-resolution (UHR) laser projector. An affordable image generator (IG) capable of driving the UHR 5K x 4K projector with high-detail scene content is of paramount importance. A viable solution to affordably meeting this need is to combine multiple digital video outputs from independent, synchronized video channels or PC-based IGs (PC-IGs).

It is not the intent of this document to define requirements related to scene content and standard flight simulation-type features commonly supported by industry. Rather, it is assumed that current state-of-the-art processing capabilities and these standard flight simulation features will be provided. Two video architectures currently supported by the UHR are described along with their associated advantages.

IMAGE GENERATOR REQUIREMENTS FOR DRIVING THE 5120 X 4096 PIXEL ULTRA HIGH-RESOLUTION LASER PROJECTOR

Scope

This document describes the architectural design concepts and defines the requirements for driving the Air Force Research Laboratory (AFRL) ultra high-resolution (UHR) laser projector. An affordable image generator (IG) capable of driving the UHR 5K x 4K projector with high-detail scene content is of paramount importance. A viable solution to affordably meeting this need is to combine multiple digital video outputs from independent, synchronized video channels or PC-based IGs (PC-IGs). It is not the intent of this document to define requirements related to scene content and standard flight simulation-type features commonly supported by industry. Rather, it is assumed that current state-of-the-art processing capabilities and these standard flight simulation features will be provided. Two video architectures currently supported by the UHR are described along with their associated advantages.

Overview

Air Force fighter pilots require eye-limited resolution for many simulator training scenarios and tasks. However, the field-of-view, brightness, and contrast of practically every visual system available today is far less than what the pilot sees looking out of the real aircraft. Because of this, current visual systems do not provide a pilot with adequate or eye-limited visual definition. To provide eye-limited or 20/20 visual acuity in a Boeing-St. Louis Visual Integrated Display System (VIDS) and the Air Force's Mobile Modular Display for Advanced Research and Training (M2DART), a UHR projector capable of displaying an unprecedented resolution of 5,120 pixels by 4,096 lines at 60 Hz frame rate is required. AFRL, in cooperation with Evans & Sutherland Incorporated (E&S), is developing a laser projector based upon the Silicon Light Machines grating light valve to meet this order-of-magnitude performance increase over current technology. This document describes the image generator interface, features, and capabilities required to provide imagery to this new class of projector.

Two Architectures

The first architecture, which is called "Standard Raster" has the advantage of using commonly available video formats as inputs and is output as a combined tiled format. The second architecture, called "Column First," uses unconventional video formats as inputs and outputs a combined striped format. This striped output is advantageous when used to drive the linear array spatial light modulator because the modulator is capable of painting one entire column of video as soon as it is received. However, most current graphic adapters do not support these unconventional formats. Both architectures have the following in common:

- Eliminate blending issues normally associated with analog video combining techniques.

- Enable dramatic increases in scene complexity by having each IG compute independent sections of a UHR projector's field of view. The additional scene complexity that can be achieved will be related to how well the associated software and terrain databases are optimized for the selected IGs.

- Allow for timing differences that can result from acceptable tolerances between independent video inputs, only requiring that their frame rate to be locked to within a defined tolerance.

- Video inputs must be in compliance with the Digital Visual Interface (DVI) specification. In addition, the video format being output from the independent IG channels must be of the same resolution and be noninterlaced.

- Use each independent IG channel's recovered DVI clock to write data into the projectors video buffers.

Figure 1 shows a block diagram, which applies to both architectures, using 16 independent PC-IG channels to drive a UHR projector. The fundamental deference of the two architectures resides within the projectors video buffer and will be described later.

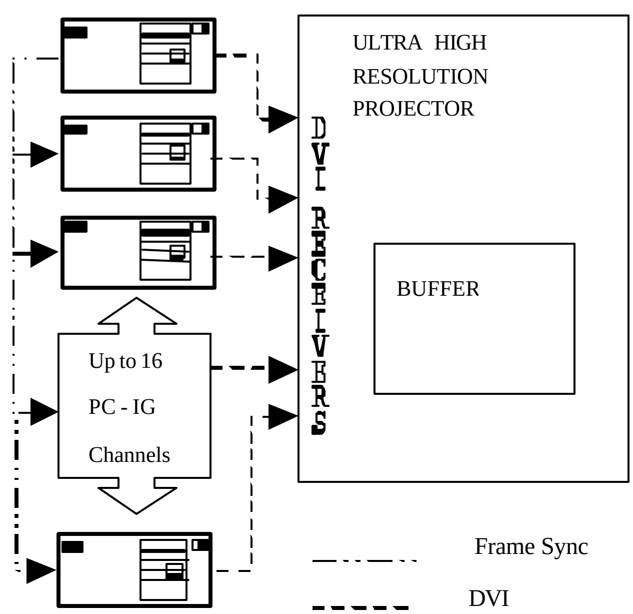

Figure 1. Hardware Block Diagram for Both Approaches.

In the following description of the tiled Standard Raster approach, 16 progressively scanned 1280 x 1024 at 60 HZ video inputs are used. The 16 IG video outputs are frame synchronized and each output fills a specified section of the projectors double-buffered frame buffer. These frame buffers are large enough to support the desired output resolution at 12 bits per color. This equates to 5120 x 4096 x 36 = 755 megabits or 95 megabytes per buffer.

As stated previously, the projector's buffers use each independent video input channel's recovered DVI clock to write information into specified buffer locations. The significance of using each independent channel's recovered DVI clock, to write that channel's information into a common frame buffer, is that it enables the incoming video to only be frame locked instead of pixel locked.

While one of the projector's two frame buffers is being filled, the other frame buffer is being read (one scanline at a time) using a common clock, by the UHR projector. Figure 2 shows a representation of this tiled video output, each square being the area one video input would have produced and sent to the projector's frame buffer.

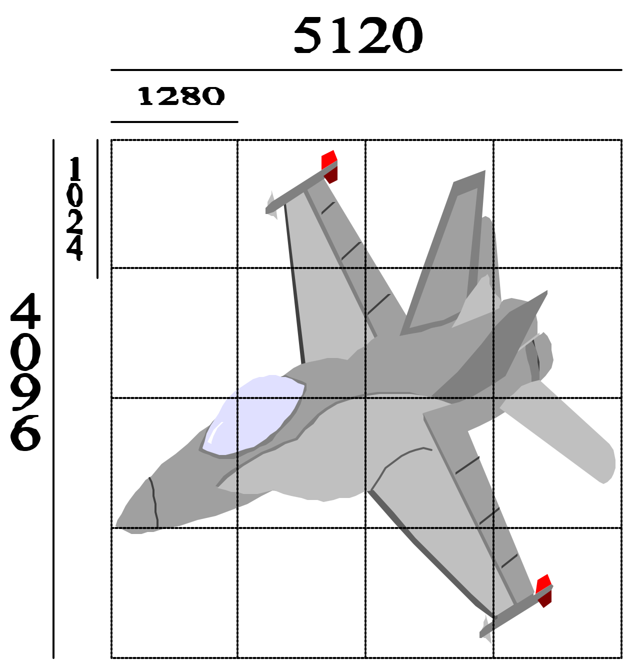

Figure 2. Sixteen Standard Raster 1280 x 1024 Formats**.**

Each of the video inputs used to support this illustrated example would have a DVI operating at 80 million pixels per second. At the 60 HZ frame rate, the DVI specification (DDWG, 1999) supports a 165-million pixel bandwidth in single-link mode and 330-million pixel bandwidth in dual-link mode. This means that the number of video input channels could be potentially reduced to eight in single-link mode and four in dual-link mode, drastically reducing associated IG cost. This potential reduction can be achieved when each IG's video channel becomes capable of producing these bandwidths, while supplying video of the quality required to support the task being simulated.

Unfortunately, the tiled frame buffer architecture contributes an additional frame time of throughput delay. For fixed-wing aircraft simulations, this additional lag time may be unacceptable. The UHR projector will ultimately be capable of receiving and displaying a parallel column of 4096 pixels. This equals one dimension of the 4096 x 5120 video format to be displayed. A striped video architecture can be used to supply "Column First" video, there by significantly reducing the throughput lag time.

Figure 3 shows a striped video architecture. In this illustration, each of the 16 IG channels would be responsible for supplying a long vertical stripe of video. Each stripe would be 256 pixels wide and 5120 scanlines long. The minimized throughput delay is the consequence of the striped video architecture and being able to read from the first part of the buffer while the remaining buffer area is still being filled. In this approach, each of the frame-synchronized DVI inputs would be allowed to write into its own area of the video buffer utilizing its own DVI clock. After the first part of the buffer is filled with several scanlines, the buffer starts outputting the first lines of video for the projector to display, while the remaining buffer area is still being filled. The vertical blanking is made long enough to compensate for any differences in individual IG channels frame completion times. The frame sync is not sent to the IG channels until after all the channels have completed their frame.

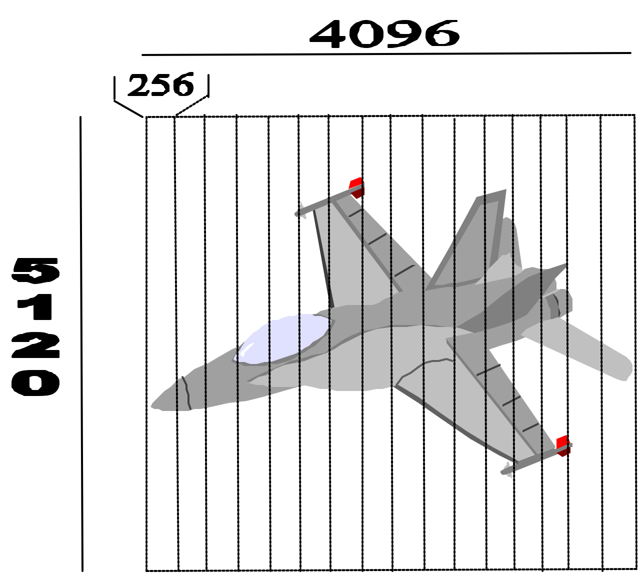

Figure 3. Sixteen Striped 256 x 5120 Column First Formats.

The Column First approach has the same potential reduction in the number of video input channels that the Standard Raster approach has, down to eight in single-link mode, and four in dual-link mode. Figure 4 shows the Column First format in the more conventional 5 x 4 aspect ratio. It is produced in the same way, and has the same advantages, as that of Figure 3. In fact, it is accomplished by doing nothing more than rotating the projector 90 degrees, and instructing each IG channel to roll its perspective correspondingly by 90 degrees. This can cause some confusion, because what is normally considered to be each IG channel's horizontal pixels are now being displayed vertically and vice versa.

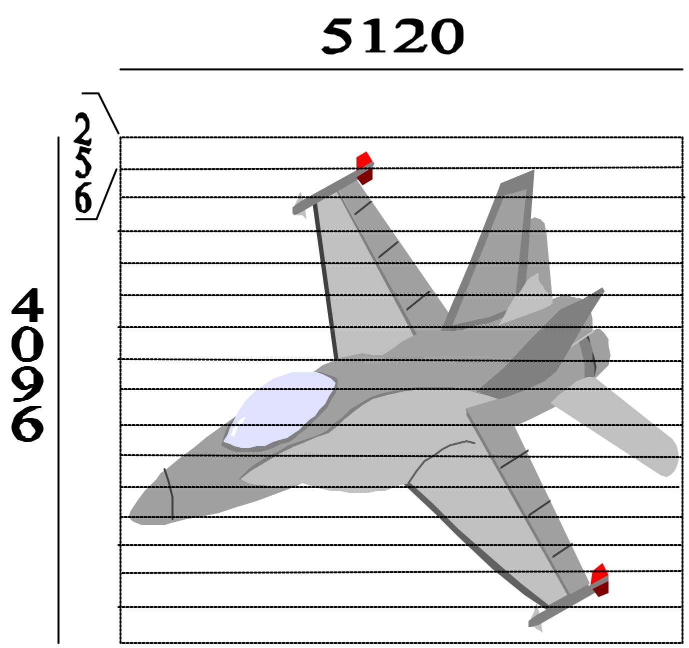

Figure 4. Column First Approach Shown with a Conventional 5 x 4 Aspect Ratio

IG Features/Capabilities

The intent of this document is to define minimal requirements that are related to projector control and image quality. The following are the minimum additional features the IGs must provide while supplying 60 Hz video of the quality required to support the task being simulated.

Anti-Aliasing

Each IG channel must be capable of providing a high-quality, anti-aliased graphics scene. The initial requirement is for a 1920 x 1080 resolution, 60 Hz image with anti-aliasing capability that provides *quality equivalent to* 16x precision (4 x 4 subpixel grid). This will be used to assess anti-aliasing requirements for the UHR projector. It is not the intent to define how the anti-aliasing is achieved, but it is the intent to define the minimum quality of the anti-aliasing that is acceptable.

Defining Fields of View (FOV)

Each IG's FOV shall be definable by the user. Centered and off-centered fields of view shall be supported, allowing for on-axis and off-axis image projection.

Distortion Correction

Correction for bow tie distortion is required. This distortion is a side effect of sweeping the light, reflected off a vertically mounted, one-dimensional linear array in the horizontal direction across the screen. It is a result of the projector's rays expanding in height as the throw distance increases. If the screen were curved with the same radius as the projector throw distance, this distortion would be eliminated.

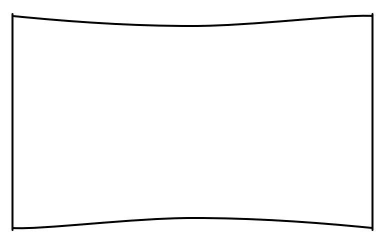

Figure 5. Bowtie Illustration

Image and Sweep Reversals

The IG shall allow the user to define correctly formatted video outputs for use in rear- and front-screen projection applications, with or without a fold mirror being inserted into the optical path.

Video Output Requirements

The DVI standard is used to interface video to the UHR laser projector. Up to 16 full-bandwidth (166 MHz 24-bit/pixel), single-link video sources can be connected at the same time. The projector can accept any standard DVI video format as well as almost any arbitrary format.

Video Format Restrictions

The video format has the following restrictions:

1. At least three pixels (clocks) of blanking are required for each line (or column).

2. At least three lines (or columns) of blanking are required for each field.

3. Maximum pixel clock is 166 MHz per DVI input.

4. Maximum vertical resolution is 1088 (does NOT include blanking).

5. Maximum horizontal resolution is 7713 (does NOT include blanking) for fully buffered images, or 8192 (does NOT include blanking) for partially buffered images.

6. Although the laser projector is capable, interlaced formats are not currently supported.

7. All DVI Links must have the same video format.

DVI Links

The UHR projector will provide connections for 16 DVI links. Link 1 provides the system clocking, so it must always be connected. If more than one DVI link is required, then they must be connected in contiguous order. For example, if two DVI links are used, the connections must be made to Link 1 and Link 2. If three or more DVI links are used, the connections must be made to Link 1, Link 2, Link 3, and so forth

Synchronization

If more than one DVI link is used, the video on each link must be vertically synchronized with each other with a maximum error of 8192 pixels. Example: for a 4096 (horizontal resolution) image made from four DVI links each supplying 1024 pixels per line, the inputs must be synchronized to within eight lines of each other.

Pixel Order

The UHR projector can be programmed to allow pixels to arrive in almost any order. However, only two orders are currently supported: *Standard Raster* and *Column First*. These are described in the following paragraphs.

Standard Raster.

Standard raster pixel order requires the image to be fully buffered before it is presented to the laser projector; therefore, there is a full field of delay. The maximum output image resolution (to the laser projector) is 7713 x 1088. In this format, each of the

DVI links present its image data going left to right from top to bottom. The final image is a stitching together of all the individual link input images as shown as shown Figure 6.

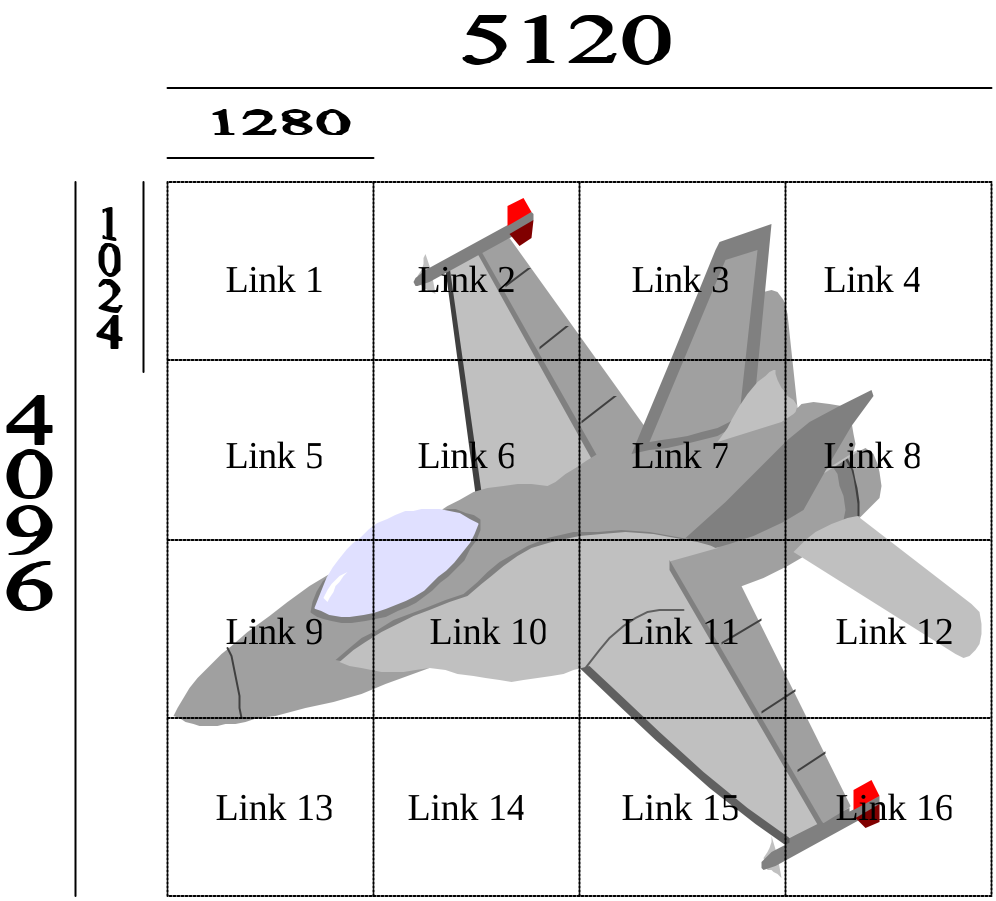

Figure 6. Standard Raster DVI Links

<u>Column First</u>**.**

Column first pixel order requires a minimum of buffering before data is presented by the laser projector. If the DVI links are perfectly synchronized, only one column of buffering (delay) is required. The maximum output image resolution (to the laser projector) is 8192 x 1088. In this format, each of the DVI links present its image data going bottom to top from left to right. The final image is a stitching together of all the individual links input images as shown Figure 7.

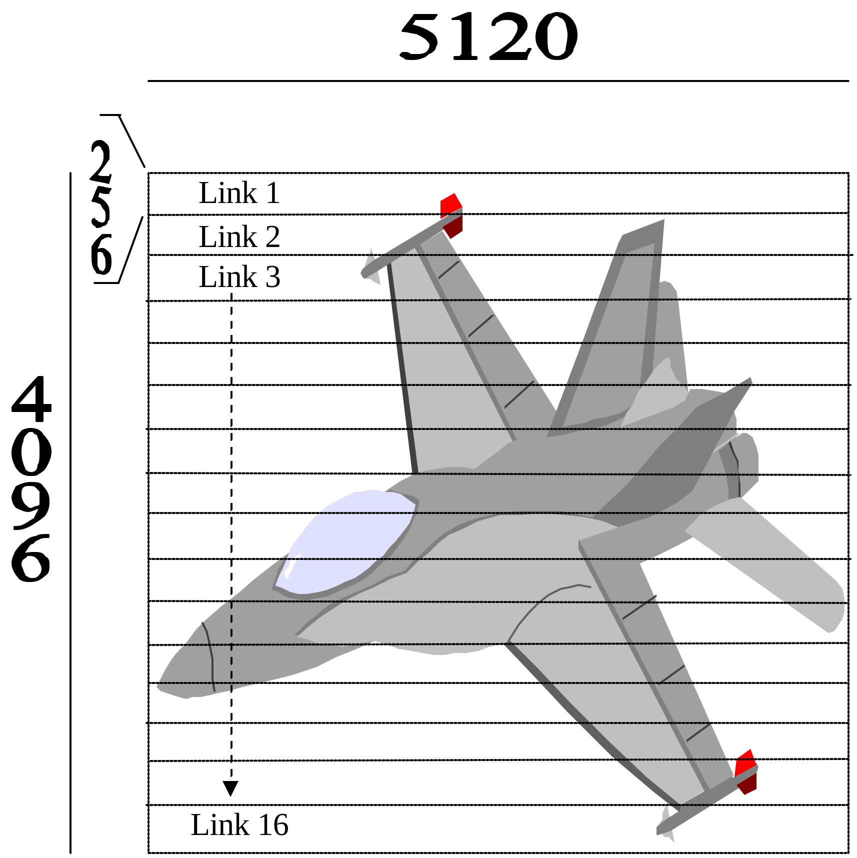

Figure 7. Standard Raster DVI

Display Data Channel Support

The projector does support Display Data Channel (DDC) specifications as defined in the DVI specification. However, it must be powered on and configured before it will respond.

Reference

Digital Display Working Group (2 Apr 99). Digital visual interface (DVI). Rev 1.0.