Leica Geosystems
DSW700 System Description

DSW700 Technical Details

Overview
Softcopy photogrammetry work, stereo-compilation, and ultimately, orthophotos can only be as accurate as the source imagery. Working in a digital photogrammetry environment requires that the scanned aerial photographs are not only as accurate as possible but that the appearance of the film is reproduced faithfully and that the raw air photos are scanned quickly so that production can begin rapidly.

The Leica DSW700 Digital Scanning Workstation is a photogrammetric scanner, designed for maximum throughput. It is capable of scanning aerial film, cut sheets or roll, black and white, color or false color, positive or negative, at a very high speed. The geometric and radiometric performances meet all photogrammetric requirements. The DSW700 includes several innovations, not only to achieve maximum speed but also to optimize radiometric performance by virtually eliminating Newton rings.

The DSW700 is built on the successful design of the earlier DSW200/300/500/600 models, based on a heavy, precise mechanical construction with moving stage plate, and stationary digital camera with state-of-the-art CCD sensor. The principal improvements over current scanner design include a novel ring light with LEDs of various colors, a high quality 11-megapixel sensor, and anti-reflective coatings on the stage and cover plates to combat Newton rings. A further innovation is the use of next generation optical encoders to position the stage, resulting in increased geometric accuracy.

Key Features
The Leica DSW700 Digital Scanning Workstation performs precision scanning of black and white, color or false color, cut or roll film negatives and diapositives at a very high speed, to provide the highest quality digital imagery for use in softcopy photogrammetric workstations.

The system consists of the following principal components:

- Heavy mechanical construction, with stage plate mechanism, to support the motorized roll-film transport, moving in the X and Y directions below the stationary illumination source and above the lens and sensor
- Dome light source consisting of LEDs of different colors
- 12-bit CCD large-array sensor to capture the image patchwise
- Convenient change of optical pixel size throughout the full 3µm to 20µm continuous resolution range, so that scanning takes place at the pixel size required by the user, without any image resampling
- High performance PC host computer running Windows® XP Professional
- Comprehensive, flexible software to control all aspects of the scanning operation, facilitated by an easy-to-use graphical user interface.

The XY stage is built to very high mechanical standards, taking into account that both cut and roll film must be accommodated. The stage is exceptionally sturdy and provides independent positioning with respect to the X and Y sensor axes. Mounted on the base are the optics and 12-bit digital sensor used to digitize the transparencies. The optical path has been minimized for optimal performance: no beam splitters or folding mirrors are used and the light path is straight. The stage and optical path are mounted inside a specially designed enclosure, which prevents dust and dirt from accumulating on the film or extraneous light from entering the system during scanning. Illumination is provided directly by an LED dome light supported above the stage. This cool light source is located 125 mm above the platen, so does not subject the film, stage or optical path to unwanted heat. The dome consists of LEDs of different colors to allow for color as well as black and white images to be scanned.

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Hardware characteristics

1. **Basic design** The DSW700 has at its center an extremely rigid base plate, manufactured as a precision casting. This is supported on a frame, furnished with casters and stabilizers (leveling screws). On the base plate are mounted precision steel rails, which derive their flatness from the base surface together with a jack screw approach, which ensures straightness before the rails are screwed tight in their final positions. Both X and Y stages are milled from aluminum. A back-lit panel mounted on the lower stage enables the operator to view a section of the film, for example to select a particular exposure for scanning. An automated motor and cam arrangement raises and lowers the glass cover plate automatically, under software control, to permit roll film to be transported. For cut film, the operator raises and lowers this plate manually, at which point it behaves like a hinged lid.

2. **Input media** The stage accepts film transparencies, as roll film or cut film, or glass plates of any thickness. The scanning format accepts images more than 260 mm square (10.2 x 10.2 inches). Input transparencies can be color or black and white and can be positive or negative.

3. **Servo drives** The drive mechanism is a friction drive that provides excellent performance and requires little maintenance. This design has been successful on all DSW models for the past fifteen years. Modern precision positioning encoders with non-contact reading heads have been selected for improved performance.

4. **Stage accuracy** The resolution of stage positioning at any point is 0.5 µm. The accuracy threshold is a maximum 1.5 µm (0.00006 inch) root mean square error (RMSE) or better on each axis, based on computer calibration and compensation. Stage calibration is provided via automated grid plate measurement and is required infrequently.

5. **Light source and optics** The illumination system provides uniform overhead illumination over the field of view of the CCD array sensor. The DSW700 uses an LED dome light, supported in a stationary position above the stage plate. The dome consists of an array of red, green, and blue LEDs, arranged in two concentric rings.

   The new LED source is more economical, with a life expectancy of more than 10 years under constant use. Most importantly, the use of LEDs in the DSW700 allows for a much more efficient, substantially faster implementation of sequential color capture than in the past.

   Flat bed scanners sometimes produce a phenomenon called Newton rings when the film is not held perfectly flat between the pressure plates. Typically, they become visible in a color scanned image as a rainbow series of light and dark rings around nondescript points in homogeneous areas. Unless a special optical fluid is used to eliminate the air gaps and therefore the index change between two media, Newton rings will usually form. The solution in the DSW700 is to reduce significantly the formation of ring patterns by controlling one of the contributing physical factors – the reflection coefficient of the surfaces. By suitably reducing the amount of reflection between the glass pressure plates, it is possible to reduce the ring amplitude until it is virtually invisible.

6. **Digital sensor and lens** A large-format, 12-bit, CCD array sensor is fitted on the DSW700. It provides better performance than any previous model in terms of the area of the film that can be captured. Faster and larger sensors that are also lower in noise translate directly into speed and quality improvements. The new sensor also creates a cleaner, more consistent scan and allows future efforts to be redirected away from perfecting raw capture towards higher level image processing, such as dodging or automatic light balancing in roll-film scanning. A 120 mm color-corrected lens has been selected to image the film on to the sensor. This lens provides greater light throughput and low distortion. An 80 mm lens is available as an option to facilitate even higher resolution for special applications. By varying the vertical positions of the CCD sensor and lens, both of which are mounted on a rail mechanism with clamps and slow motion screws, the physical pixel size at the film plane is adjustable in the range 4.5-22 µm (0.00018-0.00087 inch). With the optional 80 mm lens, pixel sizes as small as 3 µm are possible. Raw imagery is captured and may be output at any pixel size selected by the user, up to 256x the raw pixel size at the film plane. The precise CCD image geometry and low distortion optics provide an almost distortion-free image.

7. **User control panel** The user control panel is mounted inside the upper casing of the DSW700. It has two rows of 16 buttons and a small LCD panel with four rows of characters. The panel is used to input user commands, run diagnostics, etc. It contains a small computer circuit to control the LCD display, read the push button switches and communicate with a DOS-based communications computer card. The panel may also be used for manual movement of the stage and roll-film transport.

8. **Power supplies and electronics** There are four DC power supplies: one gives 5V and 12V, one gives 40V for the motors, one gives 12-24V for the CCD sensor, and the fourth gives 24V for the LED dome light. The DSW700 runs at 3.2 amps on 110V (1.6 amps at 220V) and the peak load with a 500 foot (152 m) film roll is calculated to be 6 amps.

9. **Outer housing** The stylish skins of the DSW700 consist of two main parts. The pedestal around the base structure is made from pressure formed plastic and the top housing of fiberglass. The pedestal is dark gray, the top housing silver gray and the colored inserts Leica red. The product name is in black and the Leica logo in red on white. There is a single LED to indicate power and the top housing has a large lid for loading and unloading cut or roll film or for viewing the position of a film roll.

10. **Tools and accessories** Standard system delivery provides all special tools and accessories required for routine maintenance, lubrication and calibration, including a precision glass grid plate for checking stage accuracy, and special filters for calibration of sensor radiometric response.

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Host computer and software

1. **Host computer** The DSW700 requires a host with dual processors running the Windows® XP Professional operating system. The requirement is:

Workstation PC such as the HP XW8400

- Two Dual-Core Intel Xeon processors, 2.33 Ghz minimum
- 4 GB RAM
- 250 GB SATA hard drive (minimum)
- DVD±RW drive recommended
- Graphics card must be a PCIe graphics card with minimum resolution of 24-bit, 1152x900 and 256MB memory
- Quality color display, capable of being calibrated (must be capable of adjusting color temperature to 6500K as well as offer three gain and three bias sliders corresponding to the Red, Green and Blue channels) is desirable.
- Operating system: Windows XP Professional (SP2) 32-bit
- Serial line PCI slot card offering additional serial port connections
  - This is required since the HP xw8400 only includes one built in serial port and two are needed; one for the LED strobe control and another for stage motion communication. Details on the recommended card are below:

Manufacturer -	Digi
Model -	2-port EIA-232 Universal PCI Serial card
Manufacturer Part Number -	77000847

- Other forms of storage, for example optical disk, DAT or DLT, may be chosen as options or the SATA drive capacity may be expanded.

2. **Operating system, user interface and application environment** The PC operating system must be Windows XP Professional with Service Pack 2. The application software consists of the Leica SCAN, Image Utilities and FastDodge products. The software is GUI-based and promotes a consistent “point and select” operation in all functionality.

3. **Stage calibration** A calibrated grid plate, supplied with the system, is utilized to determine a table of corrections to be applied in real-time to the stage coordinates to achieve the final stage positioning accuracy of the system. It proceeds automatically once the operator has manually pointed to the first grid intersection. The grid intersections, spaced at 15 mm intervals, are driven to and measured automatically, using the correlator mode of operation to point precisely to each grid intersection. When all grid intersections have been measured, a table of corrections is computed. Finally, the precision estimates for the unit are calculated by scanning the glass grid, measuring the intersections in the scanned image and comparing them to the corrections built.

4. **Sensor calibration** This function performs both a geometric and a radiometric calibration of the sensor. For the geometric calibration, a calibration grid is used to determine the actual optical pixel size (the X and Y pixel dimensions are measured independently). A transformation is developed between the sensor and the stage coordinate system at 25 distinct points to model the path of light as it passes through the film, glass, and lens and ultimately strikes the sensor. The radiometric calibration uses four-color image patches and

time variable dark frame captures to determine a set of bias and gain adjustments. These adjustments are measured for every pixel in each color band to correct for variations in radiometric response over the entire sensor area, as well as discrepancies in time of exposure. The bias and gain adjustments are then saved in calibration files for later application to the image patches captured during digitization.

5. **Photo/stage orientation (interior orientation)** This function is used to establish a precise photo-to-stage coordinate transformation (interior orientation) for the input film placed on the digitizer stage. The transformation is based on the measurement of up to eight fiducial marks. It provides for transformations from a simple scale and rotation to a standard affine fit. The program assists the operator in the location of the fiducial marks, automatically slewing to their approximate positions. Real-time light control and zooming of the image is available to assist the operator in pointing (measuring a sub-pixel location). The user can easily store the coordinates of the fiducial marks with the other camera calibration data. When the fiducial marks on the first image from a particular camera are measured, their image patches are stored as templates to enable automated interior orientation of subsequent images acquired by the same sensor, essential for autonomous operation with roll film. In addition, fiducial marks can be specifically enhanced in the scan without disturbing the geometric placement. This allows scans to be made with highly readable fiducial marks.

6. **Image scanning** Image scanning, sometimes called image digitizing, and utilizes the CCD sensor to convert the image transparency into digital data for use on digital photogrammetric workstations. A large capacity hard drive is provided as standard equipment for archiving of scanned imagery. Other output devices can be provided. In standard configurations where the DSW700 is an element of a larger system, imagery can be transferred electronically over a local network, in which case GigaBit connection with Category 6 cabling is strongly recommended. Several image formats are supported, both on-the-fly and off-line, including plain raster (Band Interleaved by Line), VITec, TIFF, tiled TIFF, tiled TIFF JPEG, NITF JPEG and JPEG2000. An embedded set of minification levels may be optionally stored in the tiled TIFF formats and JPEG2000.

7. **Supporting software** In addition to the applications described above, the software package includes a number of utilities which can be used to accomplish a variety of common tasks. This set of command line utilities are most commonly applied to: reformat scanned imagery into any of the common raster formats mentioned above; have the final resolution of a digitized image re-sampled to any coarser final resolution; and convert color images to black and white, or have the final radiometric characteristics of the image modified after data collection. Additionally, since all of the utilities are executed from a command line, they may be embedded in a script or batch file to modify a large number of images at once. A powerful viewing program is also included to check the appearance of the completely scanned image.

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General physical requirements

Temperature The system should be installed in a normal, air-conditioned office environment. The operating temperature range is 21±2°C, but no equipment failures occur over the range 17-25°C.

Humidity The operational relative humidity range is 40-70%. The maximum relative humidity is 90%.

Vibration Externally induced floor vibrations must be less than 0.01g at all frequencies.

Floor space and carrying capacity The equipment can be installed in a 1 x 2 meter area with a floor carrying capacity of 800 kg.

Electrical power The required electrical supply is 60±2 Hz, 110V or 50±2 Hz, 230V nominal. The normal configuration requires a single independent 20 amp circuit.

Documentation Instruction manuals are supplied giving detailed operating procedures as well as hardware description and maintenance instructions. In addition, the normal system hardware and software documentation provided with the computer and operating systems software is included. A training manual is also available.

Specifications

Basic technology Moving stage, stop and stare, stationary CCD array

XY stage
- Geometric resolution 0.5 µm
- Geometric precision <1.5 rmse on each axis
- Scanning format In excess of 260 x 260 mm
- Speed of stage travel Maximum 100 mm/second

Roll film transport Mounted on XY stage
- Maximum spool diameter 194 mm (7.625 inches)
- Film length Maximum 152 m (500 feet)
- Film width Variable, 70-240 mm
- Frame advance speed >0.3 m/second
- Rewind speed 5 minutes for 152 m (500 foot) roll

Scanning optics and electronics
- Light source LED dome light
- Stage and cover plates optically flat glass, with anti-reflective coating
- CCD array sensor 4000 x 2700
- Sensor pixel size 9 µm
- Lens Schneider 120 mm, f/5.6, color-corrected
- Optional lens Schneider 80 mm, f/5.6, color-corrected
- Image pixel size 4.5-22 µm (3.0-4.5 µm with optional lens)
- Sample optical resolution 33 lp/mm @ 15 µm, 40 lp/mm @ 12.5 µm, 100 lp/mm @ 5 µm

Electrical power
- Input power 110/220V AC, 50/60 Hz
- Maximum load 6 amperes

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Dimensions
- Size 1238 x 1003 x 1175 mm width x depth x height
- Weight 288 kg (633 lb)

Host computer
- Workstation PC with two Dual-Core Intel Xeon processors, 2.33 GHz minimum processors
- RAM 4 GB
- 250 GB SATA Hard disk minimum
- PCIe Graphics Card, 24-bit or 32-bit at 1152 x 900 resolution and 256 MB memory
- DVD±RW drive recommended
- Operating system Windows XP Professional, Service Pack 2

Scanning software
- Calibration XY stage geometric, sensor geometric and radiometric
- Interior orientation Interactive, semi-automated, fully automatic
- Scanning formats plain raster (BIL), VITec, TIFF, tiled TIFF, tiled TIFF
  JPEG, NITF JPEG and JPEG2000

Typical scanning times* for 230 x 230 mm aerial photograph
- 12.5 µm black and white 1.5 minutes color 3.5 minutes
  - Film advance and automated interior orientation 30 seconds
- 20 µm black and white 1.2 minutes color 3 minutes
  - Film advance and automated interior orientation 30 seconds

* All scan times include on-the-fly rescaling, sharpening, user specified file format, re-orientation (flip, rotate), overview and histogram generation, using a PC similar to the one specified above.