Digitizing Satellite Imagery: Quality and Cost Considerations*

Jon Leachtenauer, Kenneth Daniel, and Thomas Vogl

Abstract

The recent declassification of major U.S. satellite reconnaissance programs offers a significant source of imagery to the civil community. With nearly two billion square kilometres of coverage collected over a 12-year period, a rich database of imagery will become available to environmental researchers, archaeologists, historians, and other users of archived imagery. Imagery collected by the CORONA, ARGON, and LANYARD systems pre-dates Landsat and Earth Resources Technology (ERTS) coverage and, thus, extends the historical archive of satellite imagery by 12 years.

Unlike Landsat and ERTS imagery, however, the CORONA/LANYARD/ARGON imagery was collected with film-return systems. For many potential applications, it will be desirable to place the data in digital format. This will require digitizing the film records.

The National Exploitation Laboratory recently completed a study designed to determine the impact of digitizing resolution on the information content of the resultant digitized products. A sample of imagery (duplicate positives) was digitized with a sample of digitizers at various digitizing spot sizes. The digitized data were displayed in softcopy, and imagery analysts compared the softcopy images to the original hardcopy products. Information loss was measured in terms of the National Imagery Interpretability Scale (NIIRS). Results of the study provide the basis for selection of digitizer resolution as a function of information/bandwidth trade offs. A brief assessment of relative costs as a function of digitizer resolution was also made.

Introduction and Background

In February of 1995, President Clinton signed an executive order which declassified the imagery collected by the ARGON, LANYARD, and CORONA satellite reconnaissance systems (MacDonald, 1995a). These systems operated over the period 1959 to 1972 and collected over 1750 million square kilometres of intelligence imagery worldwide (MacDonald 1995b).

Ground resolution of the imagery reportedly ranges from 12.2 metres to better than 2 metres. An additional 343 million square kilometres of mapping coverage at ground resolutions of 30.5 to 122 metres were also collected (MacDonald, 1995b). Imagery collected by these systems is being released through the USGS EROS Data Center.

The imagery collected by the CORONA system in particular pre-dates that collected by Landsat and its predecessor, the Earth Resources Technology Satellite (ERTS), by 12 years. It thus extends the historical record of satellite imagery to a 35-year period. Further, most of the CORONA[1] imagery is of higher resolution than that collected by Landsat and ERTS. Unfortunately, however, the CORONA coverage is not synoptic. Much of the coverage is concentrated over non-domestic areas and emphasizes denied or formerly denied areas of major intelligence interest during the cold war. Further, the imagery was collected on film of varying resolutions. The more recent and more significant systems in terms of quality and coverage reportedly had film resolutions on the order of 120 to 160 lp/mm for panchromatic coverage (MacDonald, 1995b). A limited amount of color and color infrared coverage at coarser resolutions was also acquired.

For many applications, it would be most desirable to use the imagery in digital format. This would facilitate computer-aided analysis of the imagery, change detection studies using more recent commercial sources of satellite imagery, and merging of data with GIS databases. Using CORONA imagery in digital format requires that it be digitized using any one of the many commercially available digitizers. Digitizing imagery requires a trade off between quality and bandwidth (or cost). Quality can be defined in terms of information content or resolution, while bandwidth is defined in terms of time (to digitize and store) and volume (of digitized data), which in turn relates to cost.

A review of the literature found no definitive guidance on the trades between digitizing resolution and quality or information content. Sampling theory suggests a spot size equal to half the film resolution (two spots per line pair); a Central Imagery Office publication (Central Imagery Office, 1995) suggests a digitizing resolution equal to the film resolution (one spot per line pair). A recent article by Luman *et al.* (1995) indicated that a pilot study showed that digitizing spot sizes of 31 to 42 μm were required to digitize archived aerial photographic paper prints. Paper prints typically have resolutions on the order of 10 to 15 lp/mm, which equates to 66 to 100 μm per line pair or 33 to 50 μm per line. The article further stated that a comparison of the originals with the scanned imagery showed no benefit of digitizing at the higher (31-μm) resolution.

Method

Recognizing the probable desire to digitize the de-classified CORONA imagery, the National Exploitation Laboratory per-

[1]Statements made regarding the CORONA system apply in general to the LANYARD system. The LANYARD system, however, flew only a single mission. The ARGON system was a mapping system which acquired imagery at coarse resolutions.

*A somewhat altered version of "Digitizing Corona Imagery: Quality vs. Cost," which appeared in *Corona, Between the Sun & the Earth, The First NRO Reconnaissance Eye in Space* (Robert A. McDonald, editor), American Society for Photogrammetry & Remote Sensing, Bethesda, Maryland, 1997.

ERIM International, 1101 Wilson Blvd., Arlington, VA 22209-2248.

Photogrammetric Engineering & Remote Sensing,
Vol. 64, No. 1, January 1998, pp. 29–34.

0099-1112/98/6401-0029$3.00/0

TABLE 1. CIVIL NIIRS CRITERIA

Rating Level 0

Interpretability of the imagery is precluded by obscuration, degradation, or very poor resolution.

Rating Level 1

Distinguish between major land use classes (e.g., urban, agricultural, forest, water, barren).

Detect a medium-sized port facility.

Distinguish between runways and taxiways at a large airfield.

Identify large area drainage patterns by type (e.g., dendritic, trellis, radial).

Rating Level 2

Identify large (i.e., greater than 160 acre) center-pivot irrigated fields during the growing season.

Detect large buildings (e.g., hospitals, factories).

Identify road patterns, like clover leafs, on major highway systems.

Detect ice-breaker tracks.

Detect the wake from a large (e.g., greater than 300') ship.

Rating Level 3

Detect large area (i.e., larger than 160 acres) contour plowing.

Detect individual houses in residential neighborhoods.

Detect trains or strings of standard rolling stock on railroad tracks (not individual cars).

Identify inland waterways navigable by barges.

Distinguish between natural forest stands and orchards.

Rating Level 4

Identify farm buildings as barns, silos, or residences.

Count unoccupied railroad tracks along right-of-way or in a railroad yard.

Detect basketball court, tennis court, volleyball court in urban areas.

Identify individual tracks, rail pairs, control towers, switching points in rail yards.

Detect jeep trails through grassland.

Rating Level 5

Identify Christmas tree plantations.

Rating Level 5(cont.)

Identify individual rail cars by type (e.g., gondola, flat,

box) and locomotives by type (e.g., steam, diesel).

Detect open bay doors of vehicle storage buildings.

Identify tents (larger than two person) at established recreational camping areas.

Distinguish between stands of coniferous and deciduous trees during leaf-off condition.

Detect large animals (e.g., elephants, rhinoceros, giraffes) in grasslands.

Rating Level 6

Detect narcotics intercropping based on texture.

Distinguish between row (e.g., corn, soybean) crops and small grain (e.g., wheat, oats) crops.

Identify automobiles as sedans or station wagons.

Identify individual telephone/electric poles in residential neighborhoods.

Detect foot trails through barren areas.

Rating Level 7

Identify individual mature cotton plants in a known cotton field.

Identify individual railroad ties.

Detect individual steps on a stairway.

Detect stumps and rocks in forest clearings and meadows.

Rating Level 8

Count individual baby pigs.

Identify a USGS benchmark set in a paved surface.

Identify grill detailing and/or the license plate on a passenger/truck type vehicle.

Identify individual pine seedlings.

Identify individual water lilies on a pond.

Identify windshield wipers on a vehicle.

Rating Level 9

Identify individual grain heads on small grain (e.g., wheat, oats, barley).

Identify individual barbs on a barbed wire fence.

Detect individual spikes in railroad ties.

Identify individual bunches of pine needles.

Identify an ear tag on large game animals (e.g., deer, elk, moose).

formed a study to investigate the digitizing trade space of quality versus bandwidth or cost. Based on a brief survey of the community, a sample of digitizers was defined. The sample varied in terms of digitizer type, cost, and resolution. A sample of imagery was acquired and digitized at varying resolutions. The resultant digital imagery was compared to the original hardcopy using the National Imagery Interpretability Scale (NIIRS). The NIIRS is a ten-level scale defined by interpretation tasks or criteria. The NIIRS is the metric used by the intelligence community to characterize the usefulness of imagery for intelligence purposes (Leachtenauer, 1996). NIIRS criteria sets also exist for civil applications (Hothem *et al.*, 1996). Table 1 shows the civil NIIRS criteria. NIIRS differences as a function of digitizing resolution were defined. The time re-

Table 2. Digitizer Sample

Type	Array	Type	Spot Size (μm)[1]
Photomultiplier	Flying-spot	Drum	6
CCD	Matrix	Frame-grabber	4
			8
CCD	Matrix	Slide scanner	12
CCD	Linear	Flatbed	4
			6
			8
			42

[1]Minimum spot size/spacing.

quired to digitize imagery and the storage volume required were also defined. Results can be used by researchers to make decisions regarding digitizing resolution for CORONA imagery.

Digitizers

Over the past few years, the number of digitizers on the market has proliferated, quality has increased, and cost has decreased (National Exploitation Laboratory, 1995). A survey of the market found that the medical community and the prepress market were the major current users of digitizers. In both cases, however, digitizing resolution is driven by the characteristics of the display rather than the characteristics of the input image. For publishing applications, the printing resolution and the size of the desired illustration relative to the original define the resolution used to digitize the original. For radiology applications, the size of the x-ray relative to the softcopy display addressability define the digitizing resolution. For digitizing aerial imagery, however, digitizing resolution offers a trade between information loss and quantity of information. Digitizers can be characterized in terms of their detector (photomultiplier, charge coupled device or CCD), digitizing resolution (spot size or samples per dimension), input method (drum scanner, flatbed scanner, frame grabber), and format (slide scanner, roll film, sheet film). For purposes of the current study, a "sample of opportunity" was defined based on availability within government or government funded laboratories. The sample is defined in Table 2. The sample ranged from high-end photogrammetric quality digitizers to low-end desk top scanners. In addition to the resolutions shown, multiples of the minimum were used; e.g., 8 and 12 μm for a 4-μm device. Imagery was digitized with multiple devices at 4, 8, 12, and 15 μm.

Imagery

A sample of 26 aerial images was selected from historical archives. The imagery was produced as duplicate film positives from duplicate film negatives. The image sample was selected to systematically vary in content, quality, and scale. In addition to the 26 images, an engineering target was used. The engineering target contained a step wedge of known densities as well as line targets at varying frequencies. An area on each image was identified for digitizing such that each digitized image would be 2000 by 2000 pixels in size. The imagery was digitized by the production operators of the digitizer and provided in digital form for evaluation. The digitizing process was observed and a record of the time required to digitize the sample was made. The full sample of images was digitized at the finest resolution available for each device; a subset (13) was digitized at the additional resolutions evaluated for each digitizer.

Evaluation Procedure

The imagery was displayed on a high quality monochrome monitor (100 dpi, 0.15 to 35 fL dynamic range). Seven imagery analysts provided delta-NIIRS ratings comparing one of the 8-μm softcopy images to the hardcopy original. A delta-NIIRS rating is an estimate of the NIIRS difference between two images; e.g., a rating of 0.5 indicates a half NIIRS difference. The remainder of the digitized softcopy products was compared to the original 8-μm digitized softcopy product. The engineering target was measured to define tonal transfer and the modulation transfer function. Because of a lack of time and resources, the engineering target was not provided in digitized form for several of the devices evaluated.

Results

Delta-NIIRS ratings were analyzed to determine the relationship between digitizing resolution and NIIRS loss. Engineering data were analyzed to assist in interpreting the NIIRS data. The time required to digitize as a function of resolution was analyzed to define relative costs of digitizing.

NIIRS Performance

Performance as a function of digitizing spot size or resolution is shown in Figure 1. Each data point represents the delta-NIIRS rating for a particular device/resolution averaged across images. With one exception, performance was solely a function of digitizing resolution. The exception was a drum scanner; MTF data as well as observation showed the device to be noticeably out of focus. For the remainder of the devices, performance at a given spot size did not differ by a statistically significant degree. Removal of the data point for the out-of-focus device raised the correlation value to 0.99. Results at the 4-μm resolution showed no NIIRS loss relative to the hardcopy original. This somewhat unexpected result was attributed to the greater dynamic range of the softcopy display (24dB versus about 17dB for film). A 0.5 NIIRS loss was seen at the 15-μm resolution and a one-NIIRS loss would be predicted with a resolution of about 30 μm.

Engineering Target Results

A series of line frequency targets (part of the engineering target) were scanned with a microdensitometer to define original modulation following the method defined by Lillesand and Keiffer (1987). Figure 2 shows the modulation transfer functions for four spot sizes, including the out-of-focus device. Note that the MTF for that device falls off more rapidly than that for the 15-μm device.

A 16-step tablet of known densities was also included as part of the engineering target. Scans of this target (eight pix-

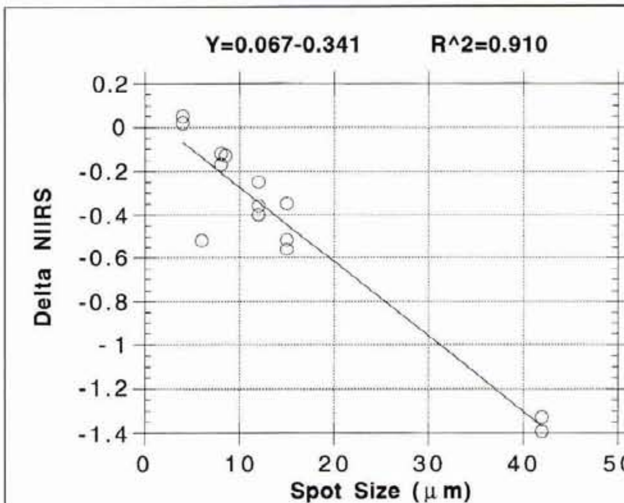

Figure 1. Effect of digitizing resolution on delta-NIIRS.

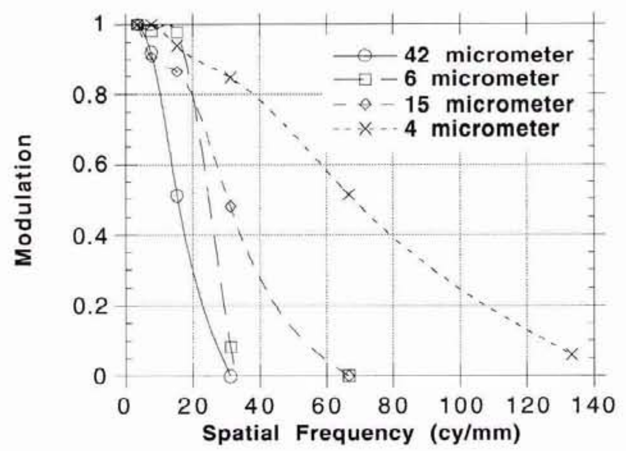

Figure 2. MTFs for four digitizing resolutions.

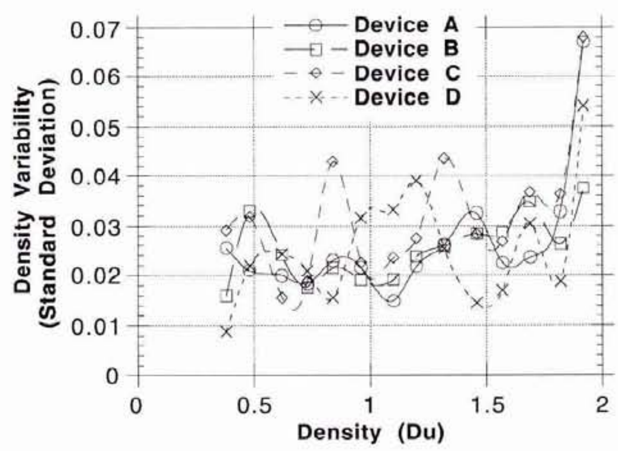

Figure 4. Density variability (noise).

els wide) were used to define the density/command level relationship for those devices where the target had been scanned. Figure 3 shows results for four of the devices. One of the devices showed saturation at the high and low end. This did not impact the NIIRS ratings; the images had been remapped before the evaluation. The remap apparently mitigated the impact of the saturation.

The step-tablet data were also used to define the noise characteristics of the digitizers in density space. The standard deviation of 64 pixel values at each of three densities was computed and converted to density space. Results are shown in Figure 4 for four digitizers at the spot sizes from 6 to 8 μm.

In general, noise (density variability) increases with density. Two of the devices exhibit greater variability than the other two. This was not reflected in any of the other measures, however. It should also be noted that, with the exception of two data points, all of the measures met the 0.03 to 0.05 D noise criteria proposed by Kölbl and Bach (1996).

Linear features of the engineering target were inspected for evidence of geometric distortion. It should be noted that the features were only 1000 pixels in length at the 4-μm digitizing resolution. With one exception, no evidence of geometric distortion was seen. The exception occurred with a 512- by 512-pixel frame grabber that used mosaicking to capture large scenes. When used at a 42-μm resolution, obvious boundary errors were noted.

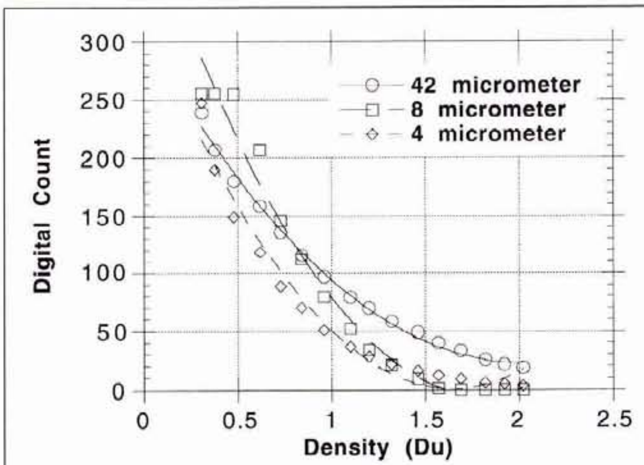

Figure 3. Density transfer function for three scanners.

Relative Costs

The image format for the majority of CORONA imagery was 55 by 757 mm. In the current study, image samples were digitized so as to provide digital images on the order of 2000 pixels square. Lossless digitizing (4-μm resolution) of a single CORONA image would result in 2.6 Gbytes of data (650 2K by 2K image chips). Accepting a 0.5 NIIRS loss (15 μm) would reduce the amount of data to 185 Mbytes of data. Accepting a one NIIRS loss (30 μm) would further reduce the amount of data to 46 Mbytes.

The KH-4A reportedly provided over 35 million square kilometres of domestic coverage (MacDonald, 1995b). A single frame covered 5240 sq km. The archive of domestic KH-4A imagery would equate to over 6700 frames of imagery. Worldwide, over 350,000 frames of KH-4A and 4B imagery are believed to be available. Lossless digitizing of these data would provide 910 Tbytes of data; accepting a one NIIRS loss would reduce this to 16 Tbytes.

It is clear that a very large set of digital data would result if significant portions of the CORONA archive were to be digitized. Assuming storage on 8-mm Exabyte tape format, the total archive (digitized at 4 μm) could be contained on 182,000 tapes that would fill a volume of 25 m^3. This is roughly five times the estimated volume of the original film.

The major cost in digitizing large volumes of data is the time required to perform the digitizing. Table 3 shows the range of times required to digitize 2K by 2K samples. Preparation time is that required to clean the film and locate the area to be digitized. It does not include any time required to locate specific ground areas on the film nor does it include time needed to annotate the film. The load and pre-scan op-

TABLE 3. TIME RANGES FOR DIGITIZING 2K BY 2K SAMPLES

Task	Time (min)
Preparation	0-2.5
Load and pre-scan	0.5-8
Scan	0.5-2.5
Store	0.5-4

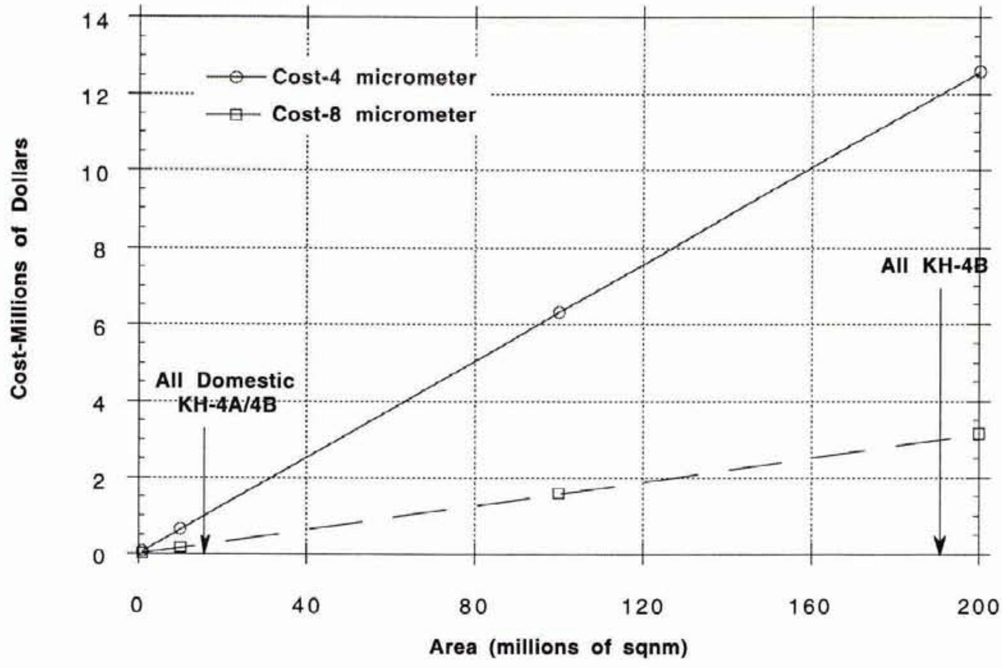

Figure 5. Effect of area and spot size on estimated digitizing costs.

eration is required to load the imagery, find the area to be digitized (a major problem with some devices), and perform a pre-scan to optimize the focus and dynamic range. The actual scanning time may be included in the pre-scan operation or it may be separate. Storage time is that needed to write the data to a hard drive or some other storage medium.

Digitizing larger formats would of course require more time per sample but would reduce overall time required. Estimates to digitize full frames of data indicated rates of three to six frames per day at a 4-μm resolution. These estimates are based on a roll film handling capability—few digitizers have this capability. The estimates also ignore data storage problems. Some digitizers are limited in the amount of data that can be stored before transfer to the final storage medium.

For large volumes of data, the major bottleneck is the time required to record to a permanent storage medium. Writing to an 8-mm Exabyte tape can be accomplished at a rate of 500 KB per second. A single frame of KH-4A imagery digitized at 4 μm (2.6 GB) would require 1.4 hours to write to tape. At this rate, recording the total KH-4 archive would require 236 years (assuming a single recording device operating 40 hours per week for 52 weeks a year). Clearly, this is not a practical approach.

On the basis of this and similar analyses, it was concluded that only the imagery needed for a specific area of interest should be digitized. For purposes of comparison, Los Angeles and environs would require the equivalent of two KH-4A frames for a single coverage. At 4-μm digitizing, this would equate to 5.2 GB of data and would require roughly half a day to process and store. A single Landsat frame covers 350 sq km and would require close to ten frames of KH-4B for matching; the data could be digitized and stored in two days. Coverage of the complete state of Washington would require about 75 equivalent frames of KH-4B data, would provide 195 GB of data at a 4-μm resolution, and would require over 100 hours of write time. Figure 5 provides a very rough cost estimate based on the area to be scanned. It assumes a cost of $60 per work hour and includes no equipment costs. A single thread process is assumed.

Discussion and Conclusions

Results indicate that the archived CORONA, LANYARD, and ARGON data can be digitized with no loss in interpretability relative to the original hardcopy. In fact, a slight improvement in interpretability was noted, probably due to the increased dynamic range of the softcopy medium. Lossless digitizing required a 4-μm digitizing spot size. Assuming a film resolution of 120 to 140 lp/mm, this is roughly equivalent to two samples per line pair. This is consistent with theory as well as the findings of Luman *et al.* (1995). As digitizing spot size increased, interpretability decreased. A 0.5 NIIRS loss was observed with a 15-μm spot, and a one NIIRS loss was estimated if a 30-μm spot were to be used. The impact of such losses can be assessed by referring to the NIIRS criteria (Table 1).

Although several different types of digitizers were used in the current study, no significant differences were found in the rate at which imagery could be digitized. However, this was due in part to the format of the digitized imagery (diverse small areas on larger pieces of film). If one were willing to cut and mount film as slides, a slide scanner might prove most efficient. Flatbed scanners would be more efficient if large film areas were to be digitized. Drum scanners can be efficient in digitizing several small pieces of film providing that their gray-scale or density histograms are similar.

With one exception, results showed no significant interpretability differences among digitizers at the same resolution. Results of other studies suggest that 8-bit gray-scale resolution is inferior to higher bit rates; this was not specifically addressed in the current study but is certainly consistent with theory. Given a desired digitizer resolution, the selection of a digitizer can thus be made on the basis of convenience and cost.

The digitizer market is changing rapidly and costs are decreasing, at least at the lower end of the market. A 1200-

dpi (21-μm) flatbed digitizer can currently be purchased for under $2500. Providing that a one NIIRS loss can be tolerated, such a device would be satisfactory. In 1994, devices capable of an 8-μm resolution could be purchased for under $20,000; 4-μm resolution scanners were priced as low as $40,000.

Because the market is changing so rapidly, no specific recommendations can be made for a particular digitizer. The popular personal computing literature (see, for example Stoller (1996)) is probably the best source of information for low- to mid-resolution scanners; typically, at least one comprehensive review is published each year.

References

Central Imagery Office, 1995. *USIS Standards and Guidelines*, CIO 2008, Vienna, Virginia.

Hothem, D., J.M. Irvine, E. Mohr, and K.B. Buckely, 1996. Quantifying Image Interpretability for Civil Users, *Proceedings of the ASPRS/ACSM Annual Convention and Exhibition*, Baltimore, Maryland, pp. 292–298.

Kölbl, O., and U. Bach, 1996. Tone Reproduction of Photographic Scanners, *Photogrammetric Engineering & Remote Sensing*, 66(6):687–694.

Leachtenauer, J.C., 1996. National Imagery Interpretability Rating Scales, *Proceedings of the ASPRS/ACSM Annual Convention and Exhibition*, Baltimore, Maryland, pp. 262–271.

Lillesand, Thomas M., and Ralph W. Kieffer, 1987. *Remote Sensing and Image Interpretation, Second Edition*, Wiley, p. 100.

Luman, D., C. Stohr, L. Hunt, and M. Smith, 1995. Preserving the Past: The Development of a Digital Historical Aerial Photographic Archive, *Illinois GIS & Mapnotes*, fall, pp. 2–9.

MacDonald, R.A., 1995a. Opening the Cold War Sky to the Public: Declassifying Satellite Reconnaissance Imagery, *Photogrammetric Engineering & Remote Sensing*, 61(4):385–390.

———, 1995b. CORONA: Success for Space Reconnaissance, A Look into the Cold War, and a Revolution for Intelligence, *Photogrammetric Engineering & Remote Sensing*, 61(6):689–719.

National Exploitation Laboratory, 1995. *Selecting and Using Image Digitizers*, National Photographic Interpretation Center, Washington D.C.

Stoller, P.M., 1996. Scanner Solutions, *MacWorld*, March, pp. 118–124.

(Received 30 July 1996; accepted 10 March 1997; revised 09 April 1997)

➤ ➤ FORTHCOMING ARTICLES ➤ ➤ ➤ ➤ ➤

Yehuda Afek and *Ariel Brand*, Mosaicking of Orthorectified Aerial Images.

Stéphane Chalifoux, *François Cavayas*, and *James T. Gray*, Map-Guided Approach for the Automatic Detection on Landsat TM Images of Forest Stands Damaged by the Spruce Budworm.

Warren B. Cohen, *Maria Fiorella*, *John Gray*, and *Karen Anderson*, An Efficient and Accurate Method for Mapping Forest Clearcuts in the Pacific Northwest Using Landsat Imagery.

F. Deppe, Forest Area Estimation Using Sample Surveys and Landsat MSS and TM Data.

Sheldon D. Drobot and *David G. Barber*, Towards Development of a Snow Water Equivalence (SWE) Algorithm Using Microwave Radiometry over Snow Covered First-Year Sea Ice.

Hamid Ebadi and *Michael A. Chapman*, GPS Controlled Strip Triangulation Using Geometric Constraints of Man-Made Structures.

Jay Gao and *Matthew B. Lythe*, Effectiveness of the MCC Method in Detecting Oceanic Circulation Patterns at a Local Scale from Sequential AVHRR Images.

J.R. Harris, *A.N. Rencz*, *B. Ballantyne*, and *C. Sheridon*, Mapping Altered Rocks Using Landsat TM and Lithogeochemical Data: Sulphurets-Brucejack Lake District, British Columbia, Canada.

Stanley R. Herwitz, *Robert E. Slye*, and *Stephen M. Turton*, Co-Registered Aerial Stereopairs from Low-Flying Aircraft for the Analysis of Long-Term Tropical Rainforest Canopy Dynamics.

Christiane Klöditz, *Angelien van Boxtel*, *Elisabetta Carfagna*, and *Willem van Deursen*, Estimating the Accuracy of Coarse Scale Classification Using High Scale Information.

John G. Lyon, *Ding Yuan*, *Ross S. Lunetta*, and *Chris D. Elvidge*, A Change Detection Experiment Using Vegetation Indices.

Fabio Maselli, *Ljiljana Petkov*, and *Giampiero Maracchi*, Extension of Climate Parameters Over the Land Surface by the Use of NOAA-AVHRR and Ancillary Data.

Robb D. Macleod and *Russell G. Congalton*, A quantitative Comparison of Change Detection Algorithms for Monitoring Eelgrass from Remotely Sensed Data.

Victor Mesev, The Use of Census Data in Urban Image Classification.

Jeffrey T. Morisette and *Siamak Khorram*, Exact Binomial Confidence Interval for Proportions.

S.V. Muller, *S.A. Walker*, *F.E. Nelson*, *N.A. Auerbach*, *J.G. Bockheim*, *S. Guyer*, and *D. Sherba*, Accuracy Assessment of a Land-Cover Map of the Kuparuk River Basin Alaska: Considerations for Remote Sensing.

Ram M. Narayanan and *Brian D. Guenther*, Effects of Emergent Grass on Mid-Infrared Laser Reflectance of Soil.

Demetrius-Kleanthis D. Rokos and *Marc P. Armstrong*, Experiments in the Identification of Terrain Features Using a PC-Based Parallel Computer.

Juliang Shao and *Clive S. Fraser*, Scale-Space Methods for Image Feature Modeling in Vision Metrology.

K.M.S. Sharma and *A. Sarkar*, A Modified Contextual Classification Technique for Remote Sensing Data.

Yongwei Sheng, *Yafang Su*, and *Qianguang Xiao*, Challenging the Cloud-Contamination Problem in Flood Monitoring with NOAA/AAVHRR Imagery.

Andrew K. Skidmore, Nonparametric Classifier for GIS Data Applied to Kangaroo Distribution Mapping.

E. Terrence Slonecker, *Denice M. Shaw*, and *Thomas M. Lillesand*, Emerging Legal and Ethical Issues in Advanced Remote Sensing Technology.

Thierry Toutin, SPOT and Landsat Stereo Fusion for Data Extraction over Mountainous Area.

David A. Yocky and *Benjamin F. Johnson*, Repeat-Pass Dual-Antenna Synthetic Aperture Radar Interferometric Change Detection Post-Processing.