Osborne Panoramic CD Technical White Paper

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Abstract

This paper captures the various ways of using the Osborne Panoramic CD's. We will cover uses that can produce results such as research, analysis, and comparison/contrast of land cover, biology, geography, hydrology, and geology for Oregon and Washington. Other disciplines as well, will find great benefits from the compilation of photographs, maps and databases that provide ease of use for data collection and analysis.

Uses include the planning of photographic retakes. Planning for high resolution rescans. The creation of presentations and products that contrast retakes to the originals for research, analysis and public awareness projects.

In many cases, there exists enough scientific evidence in the original images to display without contrast (newer images of the same sites). However, most of the images by themselves are mere scenes of vast, forested landscapes. These images could be contrasted with the current view to expose the subtle as well as the dramatic changes. Changes include, but are not limited to, biology and hydrology.

We will explain how to select locations worthy of retakes. All locations which have original images (some of which are not on the CD's) are worthy of retakes, given the accessibility. However, many factors make the wholesale retaking of the entire set economically prohibitive. Governmental, agencies and academic disciplines could choose to augment this set in various ways that are feasible. As a consequence, we suggest that periodic retakes of a subset of the original images would be valuable for purposeful research or creative projects.

Further, we will discuss the issues, applications, and possibilities of the various uses of the originals and retakes.

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1 History of the creation of the CD

IamWho Panoramic Imaging spent three years in development, scanning and geo-referencing the individual images to the sites. Followed by the structuring and development of the web pages that encase and present the information about the images. A point-and-click and rollover approach to navigating was seen as crucial for the usability of the CD. Cross platform (computer) compatibility was imperative, allowing the CD to work on any machine with a CD-ROM drive and a Web Browser [Hoeye98].

<picture, of the CD>

2 Disk operation and layout

2.1 Browsing

Like being on the web, linkable text appears in a colored, underlined text. Once linked the text changes color (browser independent) to show that the link as been previously traversed. Several special plug-ins are required to fully experience the content. Both Acrobat Reader from Adobe and QuickTime from Apple are required to view some of the ancillary documents and media. Neither is required to view the maps and images.

2.2 Navigating

All maps have "hot spots" for each of the colored dots. When rolling over them, different browsers will react differently. Netscape will show the name of the site in the status line at the bottom of the window. Internet Explorer will pop up a small window with the name of the site (you may need to pause in order to see this).

2.3 Bookmarking

Like all web pages, the pages on each of the CD's are book-markable. In most cases the browser will "remember" where you have been. Simply bookmark a page you want to return to later.

2.4 Drag and Drop

Most current desktop applications implement a feature called "Drag and Drop". Most browsers also implement Drag and Drop. If you want to incorporate an image into your presentation, with both applications open (the browser and your presentation authoring application) you can drag the desired image from the browser to the presentation being created.

2.5 Opening an image

If you want to perform image processing on an image, open the image in an image processing tool like Adobe PhotoShop® by either drag and drop, or using the file open dialog and traversing to the desired image. It is handy to record the path of the image from the URL entry line of your browser before attempting to open the image.

2.6 Manipulating an image

Manipulating the image may be accomplished with image processing tools like Adobe PhotoShop®. The extent of image processing is boundless, and is outside the scope of this paper.

Common manipulations include minor corrections for rotation, cropping, and image enhancement. The images on the CD have not been corrected for tonal density or rotational errors.

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3 About the Images/prints/negatives

3.1 Quality of the images in the archives (life expectancy)

The prints are aging and may only have decades before they deteriorate beyond use. Expecting the prints to remain unchanged for centuries is unreasonable. The life of a print can be greatly effected by the storage environment. The closer to freezing a print is kept the longer the expected life [Wilhelm]. The Archives [NARA] recommends storing the prints in an acid free container which is maintained 24x7 at a constant temperature and 50% RH.

Wilhelm Imaging Research, Inc., conducts research and issues regular reports on the image permanence of digital and traditional photographic print materials. Research shows that the effects of aging are nearly eliminated if photographic films and papers are kept in a near freezing environment.

4 Resolution

4.1 Latent resolving power of the images

As with all photographic processes there is a maximum resolution of any arbitrary image. All components involved in the capture (scene, lens, film), processing (development) and printing (enlargement or contact) of the image effect the effective resolution.

The estimated latent resolving power of the original images is based on the assumptions about the scene, lens, film, and paper used. A nondestructive study of prints similar to those in the Archives would reveal a more accurate prediction of the latent resolving power of the Archive holdings. Knowing the latent resolution of the images is useful in planning re-scans of select images. Since there is a latent resolution in the image it is not necessary to scan the print at much greater than the latent resolution. Scanning at a much greater resolution will not add detail, but will instead waste storage space and processing time.

Given what is known about the operation of the camera, the quality of the lens, the setting of the aperture [Osborne45], and the type of film used [Neblette42], we estimate the resolving power of the images to be from 26.2 lines per millimeter (lpmm) to 38.0 lpmm. Or 665.3 lines per inch (lpi) to 964.3 lpi. Note that these are only approximations based on estimates and the non-exact mathematical notion of calculating total system resolving power.

Equation 16.10 [Ray94] shows the process in which the basic values are used to arrive at the total resolving power.

$$(1/R_{image})^2 = (1/R_{scene})^2 + (1/R_{lens})^2 + (1/R_{film})^2 + (1/R_{development})^2 + (1/R_{paper})^2$$

The estimated values for each of the contributors to the total are:

Scene:	100,75,55,60,70 Lpmm for Violet, Blue, Green, Orange, Red [pg388 229 Neblette42]
Lens:	40-100 Lpmm [pg135 fig16.3 Ray94] [setting the aperture, Osborne45]
Film:	45 Lpmm (High speed panchromatic film [Osborne45]) [pg385 Neblette42]
Development:	500-1000000 Lpmm (since it is unknown, minimize its effects)
Paper:	500-1000000 Lpmm (since it is unknown, minimize its effects)

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The variation in the lens value is attributed to the Cameras Users Guide [Osborne45] directions for setting the aperture based on the sky conditions.

Sky	Aperture	Speed	Est. lpmm
Dull noon	F16	2sec	100
Cloudy noon	F22	2sec	70
Cloudy PM	F32	2sec	50
Sun	F45(32)	2sec	40

Gives a minimum of

$$(1/ R_{image})^2 = (1/55)^2 + (1/40)^2 + (1/45)^2 + (1/500)^2 + (1/500)^2$$
$$(1/ R_{image})^2 = 0.0001457$$
$$R_{image} = 26.2 \text{ lpmm (665.3 lines per inch)}$$

for the predominantly green foreground on a sunny day.

And gives a maximum of

$$(1/ R_{image})^2 = (1/100)^2 + (1/100)^2 + (1/45)^2 + (1/1000000)^2 + (1/1000000)^2$$
$$(1/ R_{image})^2 = 0.000694$$
$$R_{image} = 38.0 \text{ lpmm (964.3 lines per inch)}$$

for the blue casts on a overcast day.

The science of optics has progressed and now uses what is known as the modulation transfer function (MTF) [Ray94], which accounts for the continuousness of the real world (resolution is not an actual quantization). A test of the camera, and more specifically the lens, would reduce some of the ambiguity of the estimates, but would not account for the scene, film, processing, and printing. The film processing and printing will only ever be an approximation because photographic technology has progressed such that the exact films, chemicals and papers are no longer available. On the other hand the effects of the Lens and Scene can be measured via modern techniques.

As time passes, the economy of scanning at greater than the latent resolving power of the images becomes more affordable. There will come a time in the near future when the resolution of affordable scanning equipment will exceed the latent resolution of the prints in the archives. When this happens the time is optimal to rescan the images at or above their latent resolution before they degrade further.

4.2 Resolution needs for publishing

The best practice today is to scan the source material at 1.5x the print resolution. Printing of images is generally done at about 150DPI resolution. This means the if the image is expected to be reproduced inch for inch (no enlargement), scanning at 225dpi is sufficient for duplication.

The images on the CD are 100DPI and therefor should be printed at less than 1/2 inch to the inch (an enlargement of %50, a net reduction to half the original size). Since each original is 14” by 6” a printed copy from the CD should measure no more than 7” by 3”.

We have demonstrated that scanning an original at 600dpi, rescaling it to 52” by 22” followed by resampling it to 150dpi renders a very high quality and impressive enlargement when printed on a large format inkjet printer.

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<references to standard publishing practices>

4.3 Resolving power of the images on the CD

The images are on the V1 CD were scanned at 100dpi (50DPI, on the V2 CD) or 3.93 (1.96) lpmm, about 3/16th (3/32nd) of the estimated latent resolving power of the prints.

4.4 New resolution units for cylindrical images

Due to the nature of cylindrical images there exists an abstraction which eliminates the ambiguity of measurement which plague "traditional", rectilinear, photography.

The ambiguity arises when trying to use a finite resolution image to determine seen object size. Most images do not include reference data about themselves, distance from a known size object to be exact. Given this, the size of any other object can be measured as a ratio of the line counts and distances. In other words the angular resolution of the image is calculated from the known factors (reference size and distance) and used to calculate the unknown factors (object distance based on known size or object size based on known distance).

Furthermore, measurements of seen objects in rectilinear photos are not easily accomplished due to the non uniformity of the angular scale across the image. Wide-angle lenses tend to be much worse than "normal" or telephoto lenses for distorting the angular scale at the edges of the image. This distortion can make the determination of seen object size impossible, especially since the image does not self describe the distortions caused by the lens.

When rectilinear photos are enlarged (reduced) the resolution changes according to the scale factor of the enlargement (reduction). When an image is resampled to a different scale the resulting image has at most the scaled resolution of the source, not the resolution of the destination. Hens the notion of visible "grain" in some extreme enlargements of small format films. Unless there exists reference data in the image, like a ruler, and the distance that the camera was from that ruler is known (or the focal length of the lens is known) the sizes of objects not in the same plane as the ruler is indeterminate.

In the case of an image which self describes the view angle (as do the Osborne Images or a greater than 360 rotational image) the angular resolution can be extracted directly from the resampled image. This is because each vertical "line" lies on a specific vector extending from the center of the cylinder and the total lines in 360 degrees is known.

4.4.1 Resolution Arc Length (RAL)

Resolution Arc Length, a variation on LPD, is expressed in radians and is the measure of arc between adjacent resolution quantizations. The two are related by the constant $2\pi/360$. RAL is best expressed in real number of Radians. This is so because, given a distance to visible object, the RAL of the image and the count of pixels across the object to be measured the size of the object can be easily estimated, using simple trigonometry.

4.4.2 Lines per Degree (LPD)

Lines Per Degree is introduced as a way of removing the ambiguity introduced by the ability to arbitrarily enlarge (or reduce) photographic images. A fundamental property of a cylindrical image is that independent of the print size there are exactly 2π radians (360 degrees) in the images unwrapped width. The independence from enlargement size gives

rise to the ability to compare the absolute resolving power of images without knowing the exact enlargement factor of the image.

In general the LPD of an image can be calculated by multiplying the estimated lines per millimeter by the length of 360 degrees divided by 360 degrees.

LPD = LPMM * MMLength360Deg / 360

The units algebra of

Lines / Degree = Lines / millimeter * millimeters / Degree

validates the basic conversion equation. The millimeters cancel each other leaving Lines per Degree. Instances of Millimeter can be replaced with inches.

The equation will work for partial rotations too, for instance, to use 120 degrees replace the 360's with 120

LPD = LPMM * MMLength120Deg / 120

This drawing graphically shows how the LPD value is not effected by changes in image scale.

<drawing of concentric enlargements along LPD rays, illustrating scale independence>

4.4.3 LPD of the original images

The LPD of the originals can be calculated by scaling the estimated LPMM by the distribution of measured lengths. Because of the variations in the cameras there is a distribution of the MMLength120Deg across the whole population of images.

MMLength120Deg is measurable using the digitized images. However the measurement will only be within +/- 1/100th of an inch (+/- 0.254 mm) over 12.35 inches (313.69 mm). This represents a measurement error of about +/- 0.0080%.

Measurement of the distance across 120 degrees of a random sample (10%) of the originals reveals the following distribution of MMLength120Deg.

<curve, N vs. MMLength120Deg>

When multiplied by the max and min estimated LPMM of the images, calculated above, we get the two following LPD distributions.

<curve, N vs. LPDmax>
<curve, N vs. LPDmin>

4.4.4 Calculating the Angular Resolution for contemporary panoramic (swing lens and rotational) cameras

<words>

4.4.5 Calculating the Angular Resolution for digital panoramic cameras

<words>

5 How to get higher resolution scans

5.1 Self

The Archives have in the past allowed individuals to bring document scanners into the document viewing area. The only scanners, which have been allowed, are bed type scanners, ones where the document is in static contact with the document window. Paper-port scanners, ones where the sheet is moved through the scanner with pinch rollers are not allowed. This is because the transport will bend and possibly tear delicate documents. Likewise ADF (Automatic Document Feeders) are NOT allowed. You will need to develop a relationship with the archive personnel before being allowed scanning the images on your own. This may take many hours of training, observation and mentoring by archive personal before they allow and trust your ability to handle and care for the prints.

There are many handling rules to remember when handling the prints. One) a researcher must have only one folder at a time out of its box, Two) it must be placed back into the box when not in use and Three) it must be placed exactly in the same place it came from.

The images (in Seattle) have been dismounted from their original mounting boards and placed in Mylar sleeves. The archive prefers that the images NOT be removed from the sleeves. These sleeves are not photographically neutral, requiring adjustment of the scanner color density settings to counteract the filtration the sleeves impress on the image. A test scan with and without the Mylar is needed to determine how to set the scanning application brightness and contrast to overcome the effects of the sleeve.

5.2 Archive personnel or preferred service provider

This is probably the least possible method, the archives does not have the photographic or electronic imaging equipment available for the staff to operate. ~~Nor have they had any of their local reprographic firms scan or replicate the images.~~ Having them do this will be new ground for them and the cost will likely be high, as much as $20 per image. Although technically not scanning, the Archives (Seattle) has successfully sent prints to a local photo lab for film based reproduction, the cost was about $45 per print.

The scanner settings will not necessarily be optimum, nor is the operator likely to take the time to get the image properly aligned, “level”. It is not true that the images will self align to the scanner, many of the images are printed on the paper at some arbitrary angle to the edge. Many of the edges, which would be used for alignment are not cut straight. The edge of the Mylar, which the print is in, is not parallel to the “level line” of the image. The act of closing the scanner lid will cause the print to shift slightly as the air between the print and lid is being displaced.

5.3 Professional service

IamWho Panoramic Imaging has established a relationship with the archives and is prepared to rescan any image at a higher dpi and quality than available on the CD’s.

The draw back to having images scanned by IPI is that there is typically a long lead-time. For economic reasons this type of work is best preformed in batches, therefor the requests are queued into batches, and delivered upon completion. As much as six months may pass between each batch, so be prepared to wait, of course the more scans ordered the less time the queue takes to fill.

6 Using the disk to High-grade sites for potential retakes

This is the task of determining which sites are suitable and worthy for rephotographing. Issues include the level of "high drama", the confidence of known location, the non-existence of physically high platforms (used in the original survey), and accessibility. Each of these factors effect the selection of sites to be rephotographed, in many cases the cost of rephotographing a site may not be supported by the level of drama a comparison would reward. In many cases the reward will not be apparent until a retake has been done, a kind of catch-22. These techniques of elimination can be used to prioritize the use of available resources and funds.

6.1 High Drama

This kind of determination is the easiest from existing lookouts, where the original was taken. The observer can stand on the catwalk and compare the actual scene with the original picture to see if there is significant change to warrant a retake.

Other possible high drama cases can be selected by inspecting the original images and deducing the changes, which might be seen. Many of the original images overlook vast areas of obviously deforested terrain, by fire or harvesting. These sites may be prime candidates for a retake.

Another form of high drama is at sites that overlook yet to be constructed reservoirs. Many a lake have been created at the foot of a lookout, I.E. Dome Rock, Willamette N.F. overlooks what is now Detroit Lake.

<pictures of then and now of Detroit form Dome>

6.2 Confidence about location of original

The information about the location of each site contained on the CD is not guaranteed to be accurate. In some cases the ambiguity is as much as several miles. However, in many cases the ambiguity can be measured in feet.

Inspecting the images may mitigate some of the ambiguity. There were two prominent ways the scene was photographed. All three thirds from the "same" spot, and each frame from it's own location. This can be determined by inspecting the images. Many contain overlapping scenes, others do not. Overlapping foregrounds and backgrounds means that the camera was simply rotated in place between shots.

One method was to place the camera on the catwalk or ground just outside the building. Another was to place the tripod on the roof and simply rotate the camera about a common axes.

The first method is verifiable by the fact that in many shots the North image seemlessly splines with the Southeast image, which often shows the east wall or roof of the building. The Southwest image does not seemlessly spline with the other two. If this is the case it can be assumed that the camera was moved between shooting the North/Southeast and Southwest frames.

<pictures, crops of a adjacent match and mismatch>

The operation manual [Osborne45] for the camera suggests that the camera be placed at the southwest corner of the building and aligned so that the center of the image is aligned

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with 240 degrees off of true north. The Southwest image should be taken after 10:00 am and before noon, this is to avoid long shadows and or the possibility of shooting directly into the sun. The manual then directs the operator to move the camera to the north east corner of the lookout. The north image should be taken as close after noon as possible. The south east image can then be taken by simply rotating the camera to the 120 degree heading to take the southeast image, before 2:00 p.m. to avoid long shadows.

In many images, the stovepipe can be seen, out of focus in the foreground. The existence of it combined with a recorded tripod height of between 12 and 15 feet (in addition to the tower height). And the fact that all three images spline together well, foreground and background, suggests that the camera was placed on the top of the roof for all three frames. The lead photographer [Arnst86] suggested, after shooting many sites, that climbing on the roof was dangerous and unnecessary. This safety precaution is woefully over looked in later lookout publications [Keresk98]. The adherence to the revised operation is evident in the number of non-concentric (not from the same point) images in the set.

<picture, crop of a stove pipe>

6.3 High towers which no longer exist

This is the most problematic, One cannot easily know that the view has changed over time. One must opportunistically re-photographing the site, via an elevated camera or erecting a temporary equivalent platform. This can often be done using a trailer mounted HiLift.

In the cases where the original was taken at a combined tower-tripod height of less than 18 feet, a “mast” may be used. However the feedback that the position exactly matches the original will occurs well after leaving the site.

The combined elevation of the camera, tripod and building must be accounted for when creating the retake rating.

6.4 Accessibility

A temporary platform will only work in the cases where vehicle access still exists, I.E. Davis and Big Hole Butte in Deschutes N.F., both of which still have passable roads and footings which are still visible. In the case of Kelsy Mtn, Umpqua N.F., the footings are prominent yet the road is impassable, (many windfall trees crisscross the road within a mile of the summit).

This type of information will be necessary when rating each site for possible retake.

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7 How to retake the picture(s) from a selected site

Mike Hanemann [Hanemann] has taught many classes on the art of taking "retakes" of the Osborne panoramas. Most have been to agency personal. He demonstrates both the original and many options. The list that follows is in no way "definitive", other options may exist which we have not heard of.

Experience shows that transportation costs far outweigh the cost of film, if you are going to go there make sure you "take home" the shot.

- Bracket the exposure
- Use multiple rolls of film
- MAKE SURE THE CAMERA IS LEVEL!!
- Get there early. Well before10:00 am, Plan on leaving for the site earlier then expected.
- Use a light meter (most of the cameras described below are totally manual), average many spots and incident readings.
- Stay well past the 2:00 p.m. cut off time.
- Be meticulous, check every setting twice.
- MAKE SURE THE CAMERA IS LEVEL!!
- Take your time, avoid mistakes.
- Know your equipment, practice in the off season

7.1 Camera Options

Joseph Mehan's book, *Panoramic Photography*, [Meehan96] explained in great detail the options for film based panoramic photography. If you are considering panoramic photography we highly recommend it you own it as a reference. Much of the information that follows is from Mehan's book.

7.1.1 Film based

7.1.1.1 Pin Hole

The PinHole is one of the oldest and simplest forms of camera. There is one source for a panoramic pinhole camera [Mottweiler]. Totally manual and beautifully hand crafted from exotic woods it uses only paper backed 120 film. This is because the winder doesn't have a counter, so there is a window on the back that exposes the frame number printed on the paper. The shutter is timed by the photographer, forever stuck in "bulb" mode. The aperture is forever set to F200, making exposure compensation purely timed. Much experimentation is needed on the part of the photographer with this type of photography to achieve acceptable the results. Further, IPI has yet to tried this approach and cannot equivocally claim that the results will "match" the originals.

<picture of pinhole camera>

7.1.1.2 Swing lens

The original camera, which took the Osborne images, is this type of camera. This type of camera records the scene onto film with a lens and slit that rotates about the curved film plane. The resulting image is cylindrical even though it is typically viewed flat. The advantages to this type of camera is the ability to multiply expose any given frame, and the ability to capture only one third of a scene at a time.

The contemporary versions typically do not have a built in shift, as did the original camera. This means that they will capture more of the sky and less of the foreground than

did the original. They also lack the built in gradicule and the other direction setting accessories, alidade, compass, level and solar scope.

It would be extremely difficult to get the original camera operational. The 6 inch film used is no longer available, the clock motors no longer operate smoothly and consistently, they are bulky and heavy (with tripod, leveling base, and cases), weighing over 75 pounds. The one compelling reason to use the original camera is that the prints will be exactly the same scale as the original. This is a misleading assumption as there were variations in the original cameras, which caused the images to vary in size as much as 5%. One would need to determine which camera the original was shot with (a tedious but doable task) and use the same exact camera (one of the ten) for the retake.

<picture of Osborne camera>

The contemporary cameras come in two different sizes, 35mm and medium format, 120mm ("medium format"), being the most common. Both of these formats of film are readily available and easily processed. Medium format can be enlarged to match the original with standard darkroom equipment. One needs to remember to aim the center of the swing of a contemporary swing lens camera towards the same heading as the original, typically 0, 120, and 240 degrees. In some cases the originals were aimed at 60, 180 and 300 degrees.

<picture of modern swinglens camera>

The overlap will be greater that that of the originals (in some cases the originals were misaligned, not at these three azimuths). The availability of the originals at the site will enhance the ability to correctly match the heading of the retake with the original, remember to take reprints with you.

A disadvantage to this type of camera is that none of them (available today) have an autowinder. This means that if the camera is mounted on a mast, to simulate the missing tower, it must be lowered to wind the film. It is then raised to the same direction for bracketing or one of the two other directions. In either case remote shutter operation is achieved with a remote "bulb" pneumatic shutter release.

There are several contemporary options that can be used. The most notable is the Noblux, a German company that has been building this type of camera for nearly 50 years. Other contemporary manufacturers include Horizon and Widelux. One can find antique Kodak swing lens cameras at various camera swap meets, though most no longer operate and or the film is no longer available.

The medium format Noblux is often available for rental from a professional photographic equipment supply store.

7.1.1.3 Rotational

The rotational camera operates on the principle of rotating the film and the lens at the same time. The film advances by a slit behind the lens as the lens rotates in a cylinder. This type of camera is capable of recording much more than 360 degrees, even though any given scene contains exactly 360 degrees.

<picture of rotational cameras>

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Descendants of the Circuit camera, first built in the late 1800's the contemporary cameras come in several different sizes, 35mm and 120mm ("medium format") being the most popular. Both of these formats of film are readily available and easily processed. Medium format can be enlarged to match the original with standard darkroom equipment.

The ability to record more than 360 degrees gives the photographer the latitude to ignore the framing of the eventual print and concentrate on the exposure. It is common practice to shoot 720 degrees then crop the image after development.

Like the swing lens camera one needs to remember to aim the center of the swing of a camera towards the same heading as the original, typically 0, 120, and 240 degrees.

The overlap can be greater that that of the originals. It will be easy to over shoot the swing as most of the cameras do not have an accurate way of controlling the extent of the swing. This is not all that bad, as the exact cropping, to match the original, can (and likely will) be done later. The availability of the originals at the site will enhance the ability to fully cover the view of the original, remember to take reprints with you.

It is possible with a monopod and a fence level to free hand shoot a panorama from just outside the building. The camera on the monopod is held level outside the building while the shutter is released to capture 180 to 360 degrees of image.

<pictures of rotational being used on a monopod>

7.1.1.4 Conventional, wide angle lens or "panoramic camera"

This type of camera/lens configuration does not mimic the original Osborne images and is therefor not a recommended option. They are known as "rectilinear". The projection onto the film is "flat". Items at the edges of the image seem to be "warped", this is because of their near oblique angle to the film. When comparing an image taken with a rectilinear image to one taken with a rotational camera (such as the Osborne camera) the scene will diverge at the edges. This makes any single image near useless for comparison. However this type of lens/camera can be used if many overlapping pictures are taken, and you are willing to post process (with a computer) them into the equivalent cylindrical projection.

<picture of rectilinear panoramic cameras>

7.1.2 Hybrid, film and digital

7.1.2.1 Multiple exposures, warped and stitched into a cylinder

There exist many options here. The advent of computer based virtual reality has created a new class of application, the authoring tools for virtual reality. In many cases reality is just photographed and made virtual by means of navagatable panoramic images. Many vendors sell computer tools that will assemble a series of images taken at equally spaced angles into a single cylindrical image, a 360-degree panorama. Since the cost disparity is so great between readily available 35mm photography gear and the special cameras previously described, Apple Computer decided to prefect a way of creating a single panoramic image from the equally spaced images. Thus allowing existing equipment to be used in the creation of photo realistic virtual reality applications. The cost of entry is therefor lower for those who already own the basic equipment, a 35mm camera and a PC.

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The basic setup includes a fully manual camera, a wide angle lens, a tripod and a "panning head". The panning head is a detented device capable of leveling the rotation plane. The camera is mounted so that the lens's "nodal point" is directly over the rotation point. The individual frames are shot at each of the 8 to 22 detented vectors. The number of individual frames depends on the lens used, the wider the angle the less frames needed. The exposed film is developed and digitized, usually placed on a PhotoCD. The images are then "stitched" into a cylinderical panorama using one of many available stitching software packages.

<picture of professional panning head on tripod>

However, there are drawbacks to this method. Which include inferior images, resolution limitations and post processing costs.

The resolution is low when compared to that achievable with a panoramic camera. The amount of post processing necessary to see a print is greater than that of a panoramic camera. The resolution is inferior because of the amount of image process necessary to warp the original rectilinear images into the cylindrical projection. Additionally the "stitching" of adjacent images add artifacts to the image.

It is also true that the final image will suffer from noticeable banding or "scalloping" of continuous gradient scenes like skies. Sources of "banding" are: Too little overlap between images, usually from operator error or a conscious effort to be frugal with film. The use of a wide-angle lens that has an excessive amount of intrinsic vinyetting, as do the less expensive non-professional versions.

If the scene is changing more rapidly than the photographer can align the shot and snap the picture the resulting composite will have ghosts. This is most noticeable on a busy street corner where cars and people may be cut in half. It is also noticeable in a mountain top scenic when the clouds are moving, the shadows in one frame won't match the shadows in the next frame. This creates a shadow-non-shadow unrealistic region of the vegetation in the resultant image.

The advantages are that the equipment is readily available, and that given a scene which is rarely void of people, one can wait till each frame is "empty" before snapping the shot, simulating the effect of having no people in the scene.

A real disadvantage of this method is that elevating the camera and panning head more than 10 to 15 feet is not possible. The camera must be accurately rotated to each of 10 to 20 detents around the full circle. Doing so from any lift method which does not include the cameraman is not possible.

7.1.2.1.1 Broomstick panning monopod

A very inexpensive variant on this method exists. Using a broomstick, a portion of a hanger, a fence level, several rubber bands, a paper protractor and a disposable camera (or just a point and shoot 35mm) one can shoot a fairly good segmented panorama.

<picture of the "broomstick" panorama monopod>

The broomstick is sharpened to a dull point and the hanger is fashioned as a pointing needle perpendicular to the stick just above the point. The fence level is placed near the top, where it can be easily seen. The camera is banded to the side of the broomstick (in a

portrait manner) and aligned to shoot “level”. At the spot where the pano is to be shot, a copy of the paper protractor is placed on the ground, a rock (or nail) is used to prevent it from moving. The point of the broomstick is placed in the center of the protractor. The “needle” is aligned with one of the vectors on the protractor. The broomstick is leveled by observing the fence level. When ready, release the shutter. Wind the camera. Rotate the broomstick clockwise so that the “needle” is pointing to the next adjacent vector on the protractor. Again level the broomstick and press the shutter. Repeat this for each of the vectors on the protractor.

For a better setup, fashion a bracket which eliminates any offset of the lens from the centerline of the broomstick. This will compensate for near items becoming ghosts in the stitched product. The bracket could double as a self aligning mount for the camera, ensuring that the cameras film plane is indeed parallel to the centerline of the broom stick.

The protractor needs to be fashioned specifically for the camera used, as it depends highly on the Field of View (lens) of the camera. Sixteen or Eighteen equaangle vectors should be enough. There should be enough to overlap each frame 50%, that is to say that what is seen center view finder at one vector will be just at the edge at the adjacent vector.

After shooting all the pictures in the camera, get it developed. Do not have them printed, instead have the pictures put onto floppy disk (most labs provide this service). Ask that they NOT compensate the images, as compensation will cause the exposure of each to vary, making them hard to stitch together. Using any one of the available “stitching” software packages “stitch” the images together into one panorama.

This method will also work for any of a number of digital cameras too.

7.1.2.2 Fisheye lens dewarped into a cylinder

This option is possible with the aid of computer software [Dersch], but will suffer many of the same resolution, and post processing problems which plague the multiple exposure method above. Further, much of the image captured will not be usable for comparison since the originals contain only 20 degrees of foreground and 10 degrees of sky.

<picture of a fisheye lens on a body>
<image of what a fisheye will shoot>
<image of a corrected fisheye image>

7.1.3 Digital

7.1.3.1 Swing Lens

There are no known instances of digital swing lens cameras, past or present. To reiterate, the attributes of a swing lens camera are, it has a stationary body which aligns with one heading and captures slightly more or less that one third of a cylinder about that heading in one or more passes.

The issue here is that a curved two dimensional digital imaging plane is not practical or cost effective. A linear imager would most likely be employed and made to scan, vertically, along with the horizontal rotation of the lens, essentially duplicating the basic structure of a full rotational camera. Rotating a linear imager in a fixed body would also add unnecessary complexity in the signal interface between the imager and electronics.

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The one attribute of the swing lens style camera which is not yet attainable in the digital alternitive, digital rotational, is that of "aiming" the body in a particular direction and capturing the scene about the center of direction of the body.

7.1.3.2 Rotational

This is the newest (and most expensive) option. This type of camera is just now becoming commercially available. The reports so far are very positive about the quality of the result and the usability of the camera. Recording directly to a digital file has the advantage of avoiding all the costs of film, development, sampling, and post processing.

<picture of a digital (with computer) on a tripod>

One disadvantage is that the systems are not portable or as reliable as mainstream digital or film based methods.

7.1.3.3 Multiple exposure

This method is exactly the same as the above mentioned film based multiple exposure method but lacks the film, development and sampling steps. An advantage is that digital cameras are becoming capable, inexpensive and reliable. However the target market is the consumer, not the professional, which means that the available cameras lack manual controls needed for this type of photography. If the target is short lived computer delivered panoramic images this method may be valid. But if resolution and color clarity is important, film is still superior.

<picture of a digital camera on a panning head on a tripod>

7.1.3.4 Video camera

This is an intriguing alternative, the ubiquity of equipment, the amount of filming which can occur on one charge of the battery pack and the possibility of creating stereo panoramic images from the source. Scientists have developed methods of processing the video stream from a constant angular velocity rotating video camera into a pair of panoramic images that if viewed together present a stereo view of the scene captured.

This represents an additional leap in the VR world. Now, stereo panoramas can be created from off the shelf cameras. In addition, many panoramas can be recorded on commonly available videotape.

However, this method too suffers from resolution limitations, all video cameras are limited to about 500 lines of resolution (in the vertical direction, overall the images are 720x480, this will not soon change).

<picture of a video camera on a "rotator" on a tripod>

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7.1.4 Comparison Charts

7.1.4.1 Film only

	Camera Brand	Model	Support Equipment Brands (lens)	Film format	Fixed cost per node (1)	Max Horz FOV	Vert FOV	Image Projection	Resultant Image Suitable (8)	Total Field weight	Field Max Height (2)	Auto Wind	Auto bracket	Field Energy source
Swing lens	Osborne		-	6inch		124	-25 +10	1/3 cylinder	Yes(6)	75lb	8ft	no	no	Wind up
Pin hole	Kurt M		-	120		130	?	1/3 Cylinder	Yes? (6)	18lb	18ft(5)	no	no	none
Swing lens	Widelux		-	35mm	$14	140		1/3 cylinder	yes(6)		18ft(5)	no	no	Battery
Swing lens	Noblux		-	35mm	$14	140		1/3 cylinder	yes(6)		18ft(5)	no	no	Battery
Swing lens	Noblux		-	120		140		1/3 cylinder	yes(6)	35lb	18ft(5)	no	no	Battery
Swing lens	Horizon	202	-	35mm	$14	120		5/16 cylinder	Not quite		18ft(5)	no	no	Battery
Rotational	RoundShot	24/35	-	35mm	$14	360+	+/-25	cylinder	Yes	35lb	18ft(5)	yes	no	Replaceable Nicad
Rotational	RoundShot	35/35	-	35mm	$14	360+	+22 -16	cylinder	Yes (3)	35lb	18ft(5)	yes	no	Internal Nicad
Rotational	RoundShot		-	120/70 mm		360+	var	cylinder	yes		10ft	yes	no	Internal Nicad
Rotational	RoundShot		Nikon (4)	220		360+		cylinder	yes		10ft	yes	yes	Internal Nicad
Rotational	RoundShot		-	5inch		360+		cylinder	yes		10ft	yes	no	Internal Nicad
Rotational	Hultharama		Nikon (4)	120		360+	var	cylinder	yes		10ft	yes	no	Internal Nicad
Rotational	Globulux		-	35mm		360+	+/-24	cylinder	yes		18ft(5)	yes	no	Wind up
“panoramic”	Fugi,Kodak	disposable		35mm	N/A			planar	no			no	no	
16x9	Hasselblad	PanX	Hasselblad	35mm	N/A			planar	no			no	no	winder
16x9	Fugi	GX617	fugi	120	N/A			planar	no			no	no	winder

(1) Not including printing, based on 36 exposure Kodak E100 film cost and development cost, one node per roll.
(2) Without temporary platform, a.k.a. “high lift”, varies downward based on the height of a fully extended tripod
(3) Less Foreground. More Sky
(4) Nikon, Mamia, Hasselblad, … (not Canon EF)
(5) Microphone “Fish pole” as long vertical center post. The camera’s center of gravity must be located directly above the mounting threads or guy wires are required.
(6) Only if the center of view direction matches that of the original being compared to, care must be taken to match the directions.
(8) All must be enlarged to match the original 14”by 6” contact prints.

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7.1.4.2 Computer post processing required

	Camera Brands	Model	Support Equipment Brands (1)	Film format	Fixed cost per node	Max Horz FOV	Vert FOV	Final Image Projection	Resultant Image Suitable	Total Field weight	Field Max Height (2)	Auto Wind	Auto bracket	Field Energy source
Multi fisheye	Nikon		IPIX IBM	35mm	Varies (3)	360	180	Sphere	No		10ft	yes	yes	
360 reflective	Nikon		BeHere lens	35mm	Varies (3)	360	90	cylinder	Maybe(8)		10ft			
Multi wide angle	Nikon Canon…	EOS	Kaidan, QTVR, Mac	35mm	Varies (3)	360	35 -100	cylinder	Yes (4)	30	15ft (5)	yes	yes	Replaceable Battery
Digital, multi	Sony Kodak Canon …	Mavica DCS520 D30	Tiffen, Kaidan, QTVR, Mac	Disk, Card	$0	360	35-100	cylinder	Yes (4)		15ft (5)	yes	no	Replaceable Battery
Digital rotational	Roundshot		PC/Mac	Disk, Card	$0	360	170	cylinder	Yes(6)	30 (7)	18ft (9)	yes	yes	batteries
Video	any		Rotator	tape	$0	360	?	cylinder	Maybe (8)		10ft	yes	no	External Nicad

(1) Lens, diapter, panning head, SW, PC, etc
(2) Without temporary platform, a.k.a. “high lift”, varies downward based on the height of a fully extended tripod,
(3) Fixed costs for Film, Developing and Digitization can range from $6 to $30 per node, from print film and development to slide film, development and digitizing onto PCD.
(4) The wider angle lens (diopter) the better, Fixed focal length are better.
(5) Using a custom panning extension.
(6) At fixed vertical resolution.
(7) Including the necessary portable PC
(8) At reduced resolution, less than 480 pixels high
(9) Microphone “Fish pole” as long vertical center post. The cameras center of gravity must be located directly above the mounting threads or guy wires are required.

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7.2 Elevation

7.2.1 Tripod

Many options here, the largest studio tripod extends to just over 10 ft. A stepladder is a necessary accessory at this height.

<picture of a fully extended tripod and a step ladder>

7.2.2 Mast

Many options available here. Custom 10ft cable stiffened Aluminum tube [Hoeye]. End to end monopods [DeRenzo]. A collapsible aluminum hand held microphone boom, A.K.A. “fish pole” [Hoeye]. All need a heavy weight tripod onto which the extension mounts. Some are easier to level than others. A fence post level is very useful regardless. Also, in all cases the photographer stays on the ground and the camera is elevated, a remote shutter release is absolutely essential. The scene is not reviled until the film is developed. Non level images, regardless of method, are extremely difficult to “re-level” in the digital darkroom [Dersch], impossible in the classical darkroom. It is for this reason that the care should be taken to “level” the camera.

<picture of mast variants>

7.2.3 Balloon

Untested idea, use a helium balloon, like those used to advertise at spa and car dealers, to elevate the camera. Use 3 or more lines to keep the balloon from moving. The lifting capacity of the balloon needs to be twice that of the combined weight of the line, camera, and balloon itself.

There is the issue of how to level the camera once it is elevated. Commercially available camera adapters are available at a high cost. The adapters include live video for framing and remote control for aiming. This could be used to observe and set level.

7.2.4 Tower

A temporary tower is one of the most costly and laborious to set up. Either scaffolding or three ladders set as legs of a giant tripod.

7.2.5 Gantry

A trailer mounted “Hi Lift”, a common rental item, can be transported to those sites which are accessible by vehicle. It can be used to elevate the camera and photographer into position for taking the picture. Issues like safety and leveling the camera come to mind. Lifts that extend over 45ft typical require special delivery via large “lowboy” trailers. This is due to their high weight.

<picture of a gantry in use>

7.3 Doing it yourself

Given all the information above you need to decide whether or not you believe it is appropriate for you to acquire the equipment and spend the time developing the skill to shoot the photos. In many cases it is appropriate. For example, you wish to reshoot the same site at regular intervals. Making it convenient for you to simply “carry along” the necessary equipment to each site which you would be going to anyway.

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7.4 Retired USFS personnel

Retired F.S. Ethics offices Michael Hanemann, has a standing offer to retake any site (which can be easily reached by car) with a Hulturama for the cost of film, development, printing and Per Diem.

7.5 Hiring a professional photographer

7.5.1 IamWho Panoramic Imaging

IamWho Panoramic Imaging extends the offer to retake any of the many sites. We have also begun the huge effort of retaking local sites with the intention of building a stock of images that can be marketed at a later date.

Rob, principal photographer IPI, member IAPP, enjoys trekking to new sites and retaking the image. As with any photography there are many times unpredictable results and schedules are subject to weather conditions.

7.5.2 Another Panoramic photographer from the IAPP.

There is an association of Panoramic Photographers called the International Association of Panoramic Photographers [IAPP]. Their web site contains many resources for finding panoramic photographers for hire.

7.5.3 Any QTVR panographer

A related field which can perform many of the above mentioned services are the Quick Time Virtual Reality developers. They work mostly in segmented digital form, post processing the “nodes” into photo-realistic virtual worlds. Many belong to the IQTVR association [IQTVRA].

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8 Example uses of before and after panoramics

A note about scale and shift:

Each of the ten Osborne cameras produced has its own unique scale. Matching a retake's scale with that of the original is a very personal process, unique to each pair of images, original and retake. A general assessment of which camera took which pictures has not yet been done, though IPI has considered the usefulness of the data. It was noticed that there exists imprinted hints in each image as to which camera took which images. The shape of the border masks, the dimensions of the exposed area, and the operator's name all provide hints as to which camera was used.

There exist a substantial number of images that were taken prior to the development of the Osborne camera. These images are substantially smaller that these taken with one of the Osborne cameras, and lack the built-in downward shift so apparent in those images taken with an Osborne camera.

The existence of the built-in shift can be problematic when trying to match a retake with an original. Some modern cameras have a built-in up shift, making it necessary to invert the modern camera when reshooting a location, not always an easy task.

The shift is also anti-friendly to the use of the originals (and shifted retakes) in Virtual Reality applications. Often the shift needs to be removed by filling in the top or bottom of the image with a matte color such that the "level line", the horizon, is across the center of the image. VR playback environments make the assumption that the center of the logical image is the horizon, this is done to ease the complexity of the algorithms that unwarp the portion of the image being displayed.

8.1 Prints

8.1.1 How high of a scan resolution do I need?

This all depends on the intended use. If large static displays are to be created, the resolution of the finished display needs to be above 150dpi, this means that the scanning resolution must accommodate this minimum. This "rule of thumb" is true for most any reprinting from digital form.

8.1.2 Overlay or offset, how to get the most of the differences.

The techniques for "differencing" two images vary with desired purpose. In all cases there is the requirement that the images be the same scale.

In the overlay case several methods exist, subtractive, blinking, and edging. Offsetting stands alone as a method that requires only the use of eye movement by the observer. Overlaying techniques require either the interaction of the observer to cause the edge to move or the image to "blink" between versions.

Subtractive techniques require that the lighting conditions, film sensitivities, image alignment and many other factors be the same to produce a meaningful result. However this technique is very useful when aligning the before and after frames to each other.

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8.1.3 3D print

Like the old Karmal Corn flat toys whose image would change with angle of view. Called Xograpgy, the old and new image could be processed into a single print. It works by interleaving columns of each print under a plastic lentricular lens. Each lens refracts only one of the columns at a time. As the viewing angle is changed the column which is exposed changes. The observer would simply shift from left to right to see each of the images. Comparison is then done by quickly shifting the print while looking at the point of interest.

8.2 Cyclorama

A museum like presentation method where the image is enlarged enough to be hung on the curved inside in a freestanding cylinder. The cylinder would have be large enough so one or two people can stand at the center. An 8 foot in diameter cylinder, the just greater than the span of a man's extended arms, would have a circumference of 25.1 feet! The original images would need to be scanned at about 1100 dpi to achieve a print this size at 150dpi, the minimum acceptable resolution for printing.

Entry and exit mechanisms need to be incorporated, a portion of the cylinder wall could be missing or movable to allow the observers to enter and exit the exhibit. Another option would be to have a round platform in the center on which the observer stands. The bottom of the cyclorama would need to be 6 feet from the floor. The platform is a stair step that the observer climbs to see the view.

A neat twist would to have the image projected onto the cyclorama. The scene can then be change to satisfy the observer. A slide show could be developed to enhance the viewer's experience. An option would to use many flat screens in place of the curved cyclorama stand. The images would need to be segmented and corrected for each of the flat projections (not a trivial process in real time).

8.3 Presentations

The old images will commonly be used to make presentation to the public, policy makers, and fellow researchers. Inclusion of an image from the CD is easily done by saving the image to your hard disk via the web browsers "save image as" feature.

8.4 Forest planning

Most of the images predate harvests and can be used to contrast the effects of subsequent management polices on the overall changes of the forest cover [SkovlinWard95] [ApostolDiaz92].

8.5 Virtual Reality

The images could be processed into a virtual reality application. Where the user can pan, zoom and link around the environment. In this case, a kind of a time travel, allowing a user to see the vistas the cameramen saw as they made their way visiting all the lookouts and watch points in the PNW in the 1930's.

Each triptich could be processed into a "node", a single 360degree image that is capable of being played (panning, zooming and linking) in an interactive viewer. The nodes should be linked via "hotspots", which when clicked on sends the user to the referenced node. Apple's QuickTime Movie architecture provides context in which to implement and deploy this type of interactive "movie". There are many competing and emerging environments in which to author and deploy this type of Photo Realistic Virtual Reality content, most notably IBM's HotMedia.

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A missing element needed for totally imersive VR is sound. Presently the stock playback environment from the respective suppliers do not include spatial sound processing. Spatial sound is where the perceived location of sound is consistent with the visible location of the sources to that sound. When the user pans to an image of a waterfall the sound of that waterfall should be perceived to be in front of the viewer. Likewise when the user pans 180 degrees away form the waterfall the sound of the waterfall should be perceived to be behind the viewer. However in the case that the playback device is incapable of full dimensional sound a best effort should be made, such that the experience will be proportional to the quality of playback equipment being used.

With the uprising of multi channel audio systems attached to computers, and the advent of interactive DVD players (all of which sport multi-channel sound), spatial sound, which follows the selected pan angle of the viewer, will substantially improve the virtual experience. The CD games of Myst and Riven both rely on spatially correlated sound with angle of view to present the highly rewarding gaming experience.

In the case of the Osborne images sound for each “node” will need to be generated. That sound can range from simple wind noises to human conversation to stock animal whinnies to metropolitan street noise to the sound of automobiles idling. Most of the background sounds will need to be loops capable of playing continuously. Other sounds will need to be more interactive like sounds of stock animals only being herd when the cursor is rolled over the location of the animal in the picture.

Other audio tracks could consist of narration of what is seen in the image. As the user pans and zooms the audio track could describe what the user is looking at. In many cases Biological, Cultural, and Geological features exist in an image, which if explained, would greatly enhance the value of the image. These sound tracks would need to be triggered by the users pointer gestures. Touching on a feature would trigger the associated sound bite to be played (any currently playing bite would be abandoned).

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9 Related art

9.1 GIS

Geographic Information Systems (GIS) are being incorporated in all parts of societies planning processes. The advent of economical desktop computing as made it possible for data to be analyzed spatially. Questions, which once were mer thoughts, can now be answered with the use of GIS Layers.

GIS systems are databases. Given the raw data layers, answers can be generated and projected onto a map of the area of interest. For example, “high-light all land parcels for sale today which are less than $1000 per acre and have a potential view of Mt Hood.” This requires the application of rules between the “properties for sale” layer and the Viewscape layer. The answer would either be a map or a list of the sites that satisfy the query.

The Osborne images could be presented as a layer in a GIS data set. Such a layer could contain just the locations (with links to the views, then and now) or the actual seen areas.

As a mater of fact, one of the important phases of the original survey was to create the “seen area maps” [Arnst86] now known as the“viewshed” [Chrisman97]. These map overlays created in the winter of 1934, were one of the first uses of what is now known as “GIS’. Similarly the photographs could be considered an early exercise in “remote sensing”. The fist question posed to this early GIS was: “how long will it take to respond” [Arnst86] to a fire at any given point with the forest? The answer was not always easy to extract.

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10 Conclusion

The future of lookouts [Kresek98] was pivotal in the hands of advancements in technology, even in the early days. As the modes of transportation and communications improved, the need for the high initial density of "fixed point" observation platforms (lookouts) (and initial suppression, lookout turned fire fighter) diminished. Now there are relatively few lookouts left in operation. The lookouts roll is continuing to mutate with the needs of the forest management. Some simply sit as hulks, waiting for their fate. Others are still in use, but now, in the additional roll of public relations. Many still watch for fires and help the suppression effort start, other simply watch the fires burn, making sure human life is not endangered. Most report the weather on a regular basis, still, to this day, some 70 years later, being the eyes, nose, skin and hands for the local Fire Management Officer.

As promised, we explained the uses of the CD, the issues of obtaining higher resolution scans, the issues of selecting retakes and the options around taking those retakes. The images are now relatively well preserved. With the Product the accessibility to the images is much greater than ever before. With accessibility comes use, with use comes preservation. The more we preserve the past and use its lessons to guide us the better the future will be.

We hope that the Product and this paper will encourage all who use it to appreciate the enormous efforts put forth by Albert and company to record the forest landscapes as they were at the beginning of the "full suppression" era. As with the adaptive reuse currently underway for lookouts, these images too have a future well outside the original intent of the original sponsors. We can make it happen, we are the keepers of the past, we are the makers of the future.

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11.2 Individuals

[DeRenzo] Joseph DeRenzo, Panoramics Northwest, Inc. (photography methodology)
http://www.pansnw.com/

[Dersch] Helmut Dersch (PanoramaTools, photoshop plugins)
http://www.fh-furtwangen.de/~dersch/

[Hanemann] Mike Hanemann (photo retakes), Milwalkie OR

[Hoeye] Rob Hoeye, IamWho Panoramic Imaging (author, photographer)
http://www.iamwho.com

[Mottweiler] Kurt Mottweiler (inventor, pin hole panoramic camera)
http://www.cnsp.com/mdesign/

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11.3 Organizations

[IAPP] IAPP, International Association of Panoramic Photographers
http://www.panphoto.com/

[IQTVRA] IQTVRA, International Quicktime VR Association
http://www.iqtvra.org/

[NARA] NARA, National Archives and Records Administration
http://www.nara.gov

[SPIE] SPIE, International Society of Optical Engineers
http://www.spie.org

[USFS] US Department of Agriculture Forest Service
http://www.fs.fed.us/

11.4 Companies

Software	Services	Cameras	Tripods
Apple Computers	Digicraft	Sitez, RoundShot	Gitzo
IBM	IPI	Globlux	Bogan
		Hulther	Kaidan
		Noblux	HiLift
		Horizon	
		Fugi	
		Canon	
		Nikon	
		Sony	
		Kodak	

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