KITE
THE DRACHEN FOUNDATION
JOURNAL

Photographing Earth From Just Above It

Andrea Casalboni

Kite Aerials Yield Personal View

Kite aerial photography (KAP as its practitioners call it) is all about seeing the world in a new way----directly from above, but not too far above.

It's not the grand view from a high-flying airplane, or abstracted images taken from satellites in space, or wind-whipped photos shot from thumping helicopters.

Rather, it is an unhurried, rather low tech, rather personal, sometimes somewhat accidental look at our world from a few hundred feet in the sky. The hobbyist with a mechanical touch is at work here in his own silent world.

Results can be novel and charming. A case in point is this shot by Italian master Andrea Casalboni. It shows a man walking his dog on the beach at Cervia, near Ravenna. Or rather, it's pretty much an image of a shadow guy walking his shadow pooch. Mundane? Yes, but intimate and unexpected, and beautiful, too. Also amusing. "That I happened to make the shot when the dog was jumping was only good fortune," says Casalboni. A perfect kite aerial photograph.

The worldwide KAP fraternity is a dedicated one and its work is easily accessed via the Internet. Take a look. Just search "KAP" and proceed from there. There are many Websites, some quite elaborate. All are free.

For a look at some choice images produced by a scattering of hobbyists and professionals around the globe and for some general information on the pastime turn to the KAP feature section starting on Page 3.

Generating Electric Power With Kites p.32

No. 24 Summer 2007

The Journal Staff


Ben Ruhe

Scott Skinner, president of the Drachen Foundation, is a former pilot instructor at the U.S. Air Force Academy. He has been a kite enthusiast for two decades–designing, making, flying, collecting, and teaching about kites.

Ali Fujino is the director of Drachen. A museum specialist since age 19 when she began work at the Smithsonian Institution, she has long been fascinated with anything that could become airborne. Fujino is a member of the prestigious Explorers Club of New York City in recognition of her 25 years of cultural work in Third World countries.


Ben Ruhe


Malcolm Goodman

Editor of the Drachen Journal, well traveled **Ben Ruhe** regularly contributes articles to special interest publications on subjects as diverse as boomerangs, tribal art and flint-knapping.

Born and raised in Japan, **Kiyomi Okawa** came to the U.S. as a student and stayed on as a valued graphic expert. Now Drachen's graphic artist, Kiyomi lays out this Journal, among her other duties. She's been flying kites since elementary school.


Mikio Toki

How to Find This Journal

The Drachen Foundation Journal can be read online or printed out, as desired. To read it, bring up www.drachen.org, and click on Journal icon. An Adobe Acrobat Reader is needed for viewing or printing out the publication. It is available as a free download at http://www.adobe.com/products/acrobat/readstep.html

The Drachen Foundation:
Kite Archives, Science and Culture

The Drachen Foundation is devoted to the increase and diffusion of knowledge about kites worldwide. A 501(c)(3) private nonprofit corporation, Drachen views kites from the standpoint of art, culture, science and history. It uses an integrated program of exhibitions, education, research, collections management, and publications to promote learning about kites. The archive it maintains is freely open to the public for research.

Study Center Location
1905 Queen Anne Avenue North / 200
Seattle, Washington 98109-2500 U.S.A.

Office Hours
Monday–Friday 9 a.m.–5 p.m.

Research Library
By appointment only: 206-282-4349

Airborne Camera Has Unique Uses

The Beauty and Wonder of the Earth As Photographed From a Flying Kite

By Ben Ruhe

Kite aerial photography gives us a new conception and understanding of the universe. It is a unique tool in many fields of endeavor, both scientific and commercial. It has as well great esthetic impact. KAP, as the technique is called, is a superb hobby, pastime, passion, business----with so many facets it has something for everyone.

Aerial views of the earth have of course become routine in the last two centuries. Photographs are taken from balloons, airplanes, helicopters, rockets, hang gliders, and other platforms in addition to kites. But the kite platform has unique advantages. It is relatively easy to wield, inexpensive, inoffensive to wildlife and humans, flyable under conditions that may defeat rivals, available for use where the others may not be (for instance, suspicious third world countries).

Very much on the plus side, aerial photography permits major help with the environment. We can monitor a progression from yesteryear (the melting of a glacier, for example). Engineers and architects are able to best locate large projects. KAP tracks pollution and erosion, keeps track of geological faults, babysits whales to keep them from harm from instrusive tourism.

With its third dimension, it is sometimes capable of rendering an act of magic-----making the invisible visible, as in archeological work. At the very least it, provides a personal, low altitude, low tech view of the commonplace. Always educational and ever entertaining.

KAP had its antecedents in balloon ascents in the 19th century. It reached its golden age in the early years of the 20th century, exemplified by George Lawrence's panoramic view of San Francisco after the 1906 earthquake. A renaissance occurred after World War II with the development of new kites and all sorts of handy equipment. Development of the World Wide Web has now permitted hobbyists to freely post the results of their work globally.

What's ahead is potentially a step up in importance. KAP is what might be termed, with apologies, a "participatory medium." As hugely popular and increasingly influential new Internet sites using home videos and other unfiltered, unedited news show us, kite aerial photography could well assume, by accident, a political role. Consider a kite-flying amateur catching a vitally important piece of news on camera or video----say evidence of an impending major military attack somewhere in the world----and immediately beaming it globally via his computer. Quite feasible today. Millions of people learn of the discovery at the same exact moment heads of state do. The implications for this not unimaginable scenario are major.

Following is a sampling of kite aerial photographs.

Brooks Leffler

Brooks Leffler, eminence grise of kite aerial photography, gets ready to loft his camera high into the sky for a photo shoot.

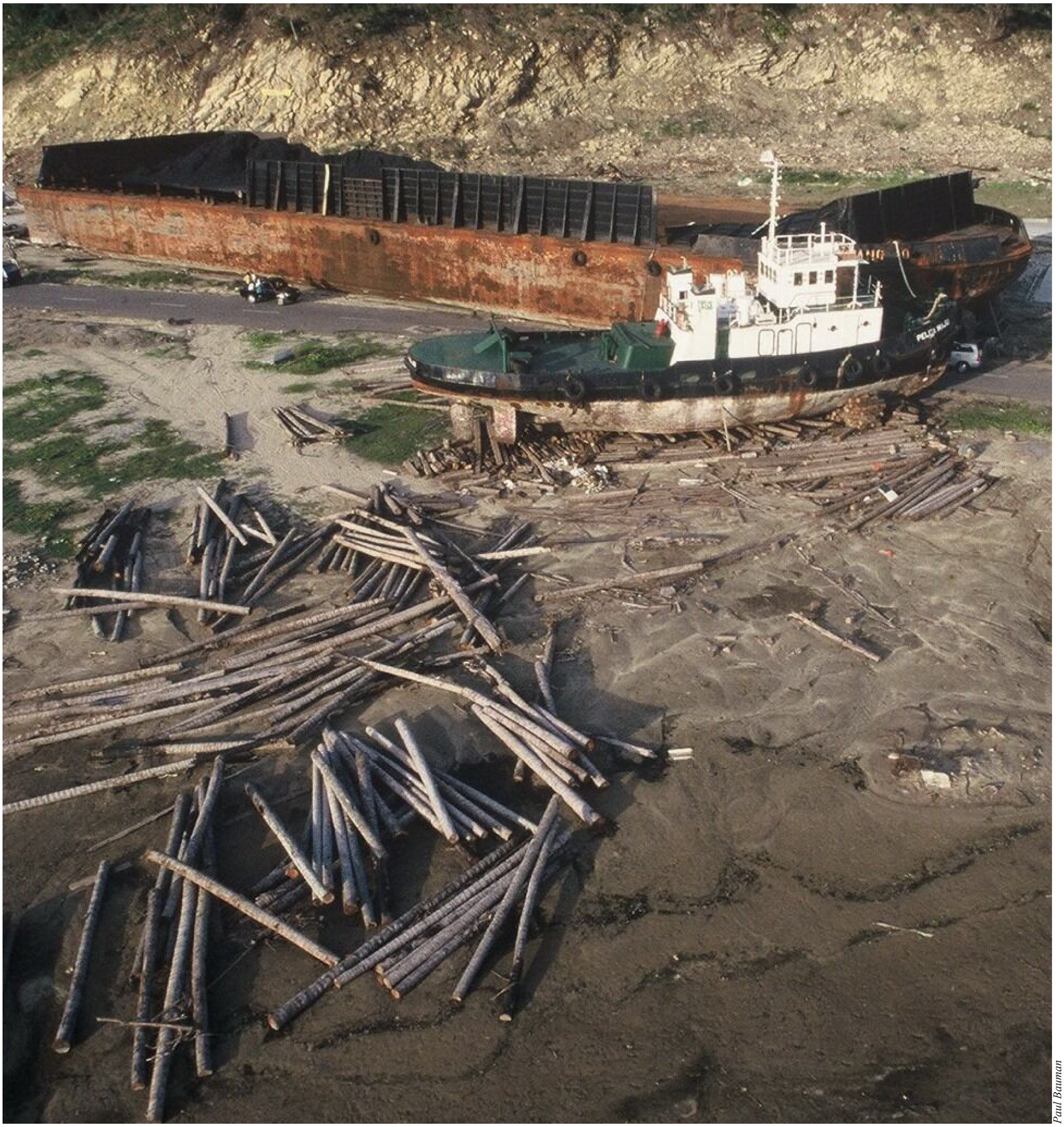
Paul Bauman

A longtime expatriate American, Bauman manages a geophysical services group for a firm in Calgary, Alberta, Canada. His group does near surface work and focuses on exploring for water and studying contamination sites. It involves itself as well in archeology, engineering, and the search for resources. Originally from Boston, Bauman has degrees from Princeton and the University of Waterloo in Ontario. In recent years he has frequently used kite aerial photography in archeological work and in the study of industrial areas with stressed vegetation. Following the Indian Ocean tsunami, he did groundwater studies in devastated Aceh Province in Indonesia on behalf of the United Nations.

Both photos by Paul Bauman

While checking for wells in Lampulo in Aceh Province, Indonesia, Paul Bauman came upon this aftermath scene. He learned the 20-meter boat was lifted by the first of the tsunami waves that struck the area and was dropped onto the second floor of the house. One man climbed into the boat and urgently summoned 43 other persons to join him. In the following two waves, almost every house in the area was flattened while the vessel stood fast. Bauman learned the story when he came upon grafitti which said, "By the grace of Allah this boat saved 44 lives." Inquiries produced the full story from refugees. The photo was made with a 7 megapixel Canon camera on an interval timer, using a simple Brooks Leffler rig without radio controls.

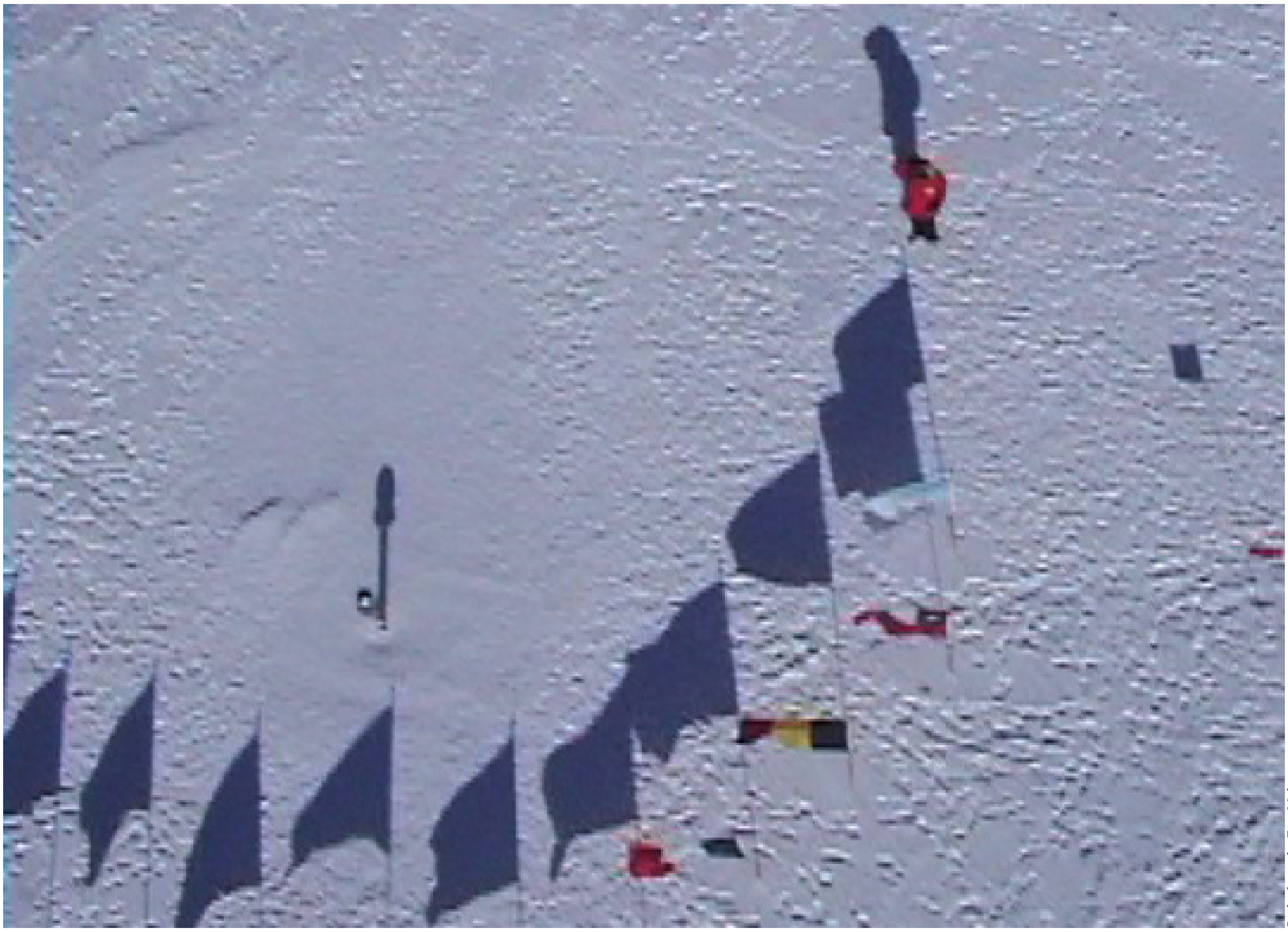
Paul Bauman



Tsunami waves lifted this large barge and tugboat out of the water and dropped them smack onto the only coastal highway in Aceh Province, in Indonesia. The road is 300 meters from the ocean. One or all three of the tidal waves that hit in rapid succession scraped the cliff in back of the boats bare of vegetation to a height of 32 meters, or close to 100 feet. The waves were so deadly some villages along the coastal strip had no survivors at all. "Seeing this photo," says Bauman, "one realizes that villages were trapped on a narrow strip between the ocean and high cliffs and were bulldozed by walls of water. Even if a person survived after the waves struck, road access for escape or for help was obliterated." Bauman used a radio-controlled rig carrying a Rebel film camera shooting Ektachrome 200 film with a 24 mm lens for this image.

Eric Muhs

A high school physics teacher in Seattle, Eric Muhs has a resume that says "Fixer of anything." The legend is both testimony to his confidence in himself and his unusually wide range of skills. Highly verbal, Muhs is one of those inspiring teachers that make a difference in the lives of students. His kite aerial photography has ranged from Hawaii where he documented Polynesian rock art to Baja, Mexico where he studied whales. He documented sites on Easter Island for an archeologist and made memorable images flying his kite over the South Pole; he also tossed a boomerang around the Pole-----a 24-hour endurance flight before the catch (since longitude markers converge there). Get it?



Both photos by Eric Muhs

While doing cosmic ray research at the South Pole for the National Science Foundation, Eric Muhs took time out to fly his two Sutton Flow Form kites in tandem and make some aerial photos. This one shows him using an autofocus Sony Camcorder to film himself at the South Pole. The temperature was minus-55 degrees. The encircling flags honor Antarctic Treaty signatory nations. "It was bright, white, dry, and high," says Muhs. "It was much brighter than the Baja Desert and the light, because the ice crystals are reflective, was like a welding torch. The high arctic plateau at the pole is the driest place on earth. The altitude is 10,800 feet, so a visitor must drink water almost constantly." He adds: "When conditions were correct and the rig aloft, I just pointed the Sony straight down, got it rolling, and walked around. The advantage was I got a lot of pictures. The downside was there wasn't great resolution. Because the camera was so big, it resisted the cold very well and I was able to film for an hour." Muhs' shot was featured on the front page of the Antarctic Sun, must reading at Amundsen-Scott Base at the pole. His reward? "Fifteen minutes of fame," says Eric. "Oh yes, I was 'Kite Guy' at the South Pole."

Eric Muhs

Eric Muhs

Mystery photograph! Everyone has seen the standard iconic shot of the lineup of moai statues at Ahu Tongariki on Easter Island but Eric Muhs, with this kite aerial photograph, managed to obtain a striking new view of the archeological display. He used a Nikon Coolpix 5000 5 mp camera at fine resolution, a Flow Form 30 kite, and 500-pound Dacron line.

One Man's Thoughts on KAP

"Kite aerial photography can be a very rewarding hobby that can satisfy many different aspects of the human psyche. It requires inventiveness and patience. It provides, in turn, a channel for creativity, an appreciation of the rewards of technique, a means of spending time out of doors in the best of weather, and a fulfilling way of spending leisure time.

"Part creative, part innovative, KAP provides an opportunity for people with technical skills and interest to express their creative side through the medium of photography. Without a doubt, the use of kites for lifting the camera brings out the inner child.

"Staying within the coherent structure of a subject, kite aerial photography seemed at first constraining, but the more I do, the more liberating I find it. KAP is a convenient topic of abiding interest that for me has endless metaphorical connections to our existence, our day-to-day life, the little victories and the setbacks, the pleasures and the pain."

----Simon Harbord, Aberdeen, Scotland

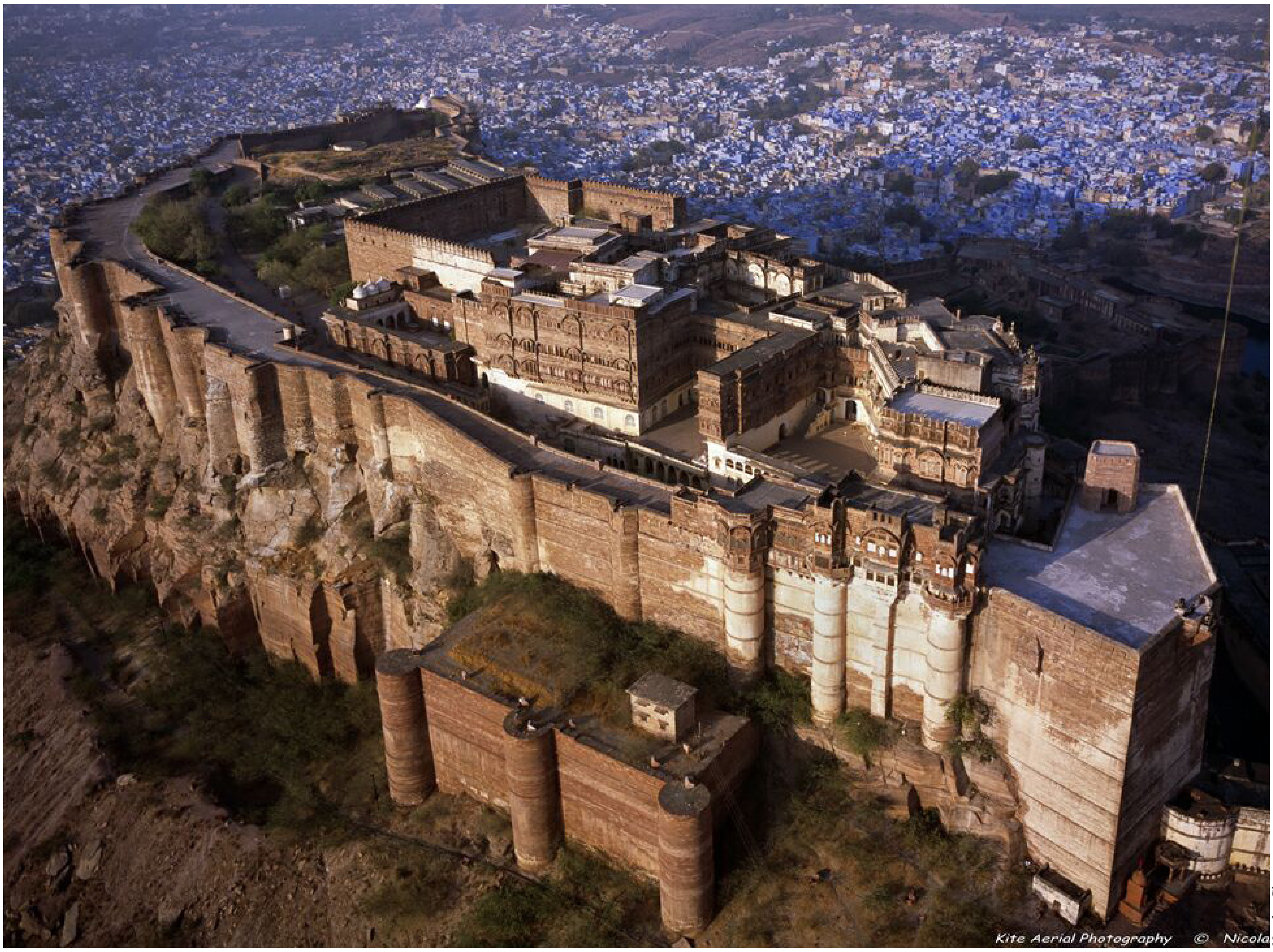
Nicolas Chorier

A full time KAP professional, adventuresome "Nico" Chorier uses Montepellier, France, as home base but wanders the world plying his trade. He has been a particular success with his strangely wonderful closeup views of the landmark Taj Mahal, in Agra, India. They brought him a measure of fame and even some fortune. (His first attempt on the Taj got him arrested, on his second go round he was backed by the local government tourist agency.) Chorier has photographed whales in Baja, Mexico, festivals in Bali, an agricultural project in Brazil, archeological sites in France. His bread and butter work though is more mundane: images for developers and town planners. Nico's goal? An assignment shooting lions in Africa.

Both photos by Nicolas Chorier

One of the most holy sites in the world is Varanesi (the former Benares), in India. Hindu pilgrims by the hundreds of thousands come to pay honor to the revered Ganges River. For this striking image, Chorier rented a small boat at dawn so he could capture the town waking up and the multitudes starting their ritual river wash to cleanse themselves of sins.

Nicolas Chorier



As part of a contract to survey properties owned by the maharajah of Jodhpur, in India, Chorier photographed the city's old fort. The photographer made thousands of shots of the fort and its sprawling premises----vertical, oblique, closeup, specific----for the maharajah's advertising and promotional purposes, but mainly to permit architects planning restoration work to understand how the structure grew over the centuries. Chorier uses a high-definition 120 mm (4/5 by 6 centimeter) size camera, a lightweight polycarbonate Fuji GA645W with wide angle lens. His kites of choice are the Rokkaku and Delta. With video monitoring, he gets exactly the picture he wants, affording both control and real savings. To eliminate hateful vibration and guard against accidental line severance and destruction of his rig, he uses a double line loosely braided together.

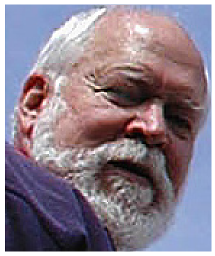
A Luckless Flight

With the invention of hand-held cameras in the 1870s, photography was so simplified anyone could take a shot anywhere by simply pressing a button. The first airman to take a dry plate camera rig aloft in a free balloon to make aerial shots, however, proved to be unusually luckless.

M. Triboulet of the Societie d'Aerostation Meteorologique photographed Paris from a height of 1,640 feet, but then was hit by a torrential rainstorm that downed his balloon in the Seine River, near the cathedral of Notre Dame.

Alert inspectors working for the city were incensed the aeronaut had entered Paris illegally without going through their customs formalities, and examined his gear for contraband. With great zeal they opened his photographic plate holders to see what was inside them, thus exposing them to light and ruining them.

Brooks Leffler



Brooks Leffler, of Pacific Grove, California, is a former television producer who has been, in his own word, “messing” with kites for a quarter of a century. He started taking pictures from a kite line in 1989 when he wanted to use a photo of a kite from above in a magazine advertisement. Dropping out of broadcasting in l982, he ran a kite shop in the Washington area before eventually moving to California. Leffler served as executive director of the American Kitefliers Association and for years edited the definitive Kite Aerial Photography Journal, a quarterly. He has conducted workshops and produced two international KAP conferences. He has designed and built on commission more than 100 aerial camera systems and sells do-it-yourself kits to the technically minded.

Both photos by Brooks Leffler

If you had a looming shadow over your blanket, would you leave too? That Delta kite shadow at Carmel beach is the work of kiteflying Brooks Leffler.

Brooks Leffler

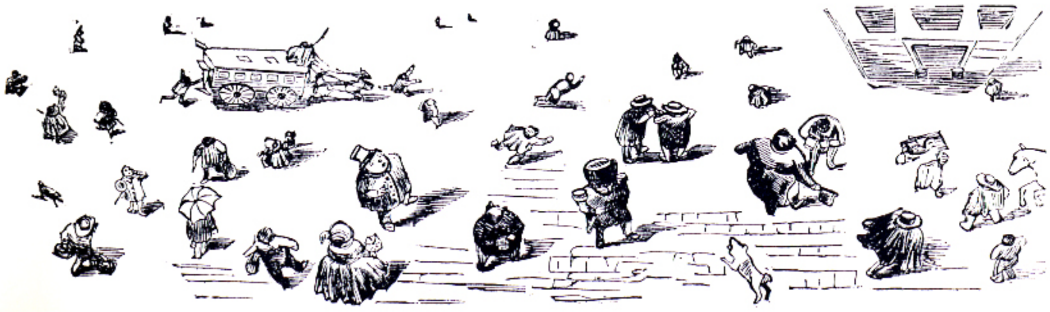
Brooks Leffler

The shoreline of Pacific Grove, California, with its May pink carpet of mesymbrianthemum flowers.

A KAP Timeline

Aerial Photography in the Early Days

1858. Gaspard Felix Tournachon (a.k.a. Nadar) takes the first aerial photograph ever, from a balloon 262 feet in the air, over the Bievre Valley, near Paris. The shot is of such poor quality it cannot be reproduced. “A simple positive upon glass, made with detestable materials,” is Nadar’s characterization. But aerial photography is born.



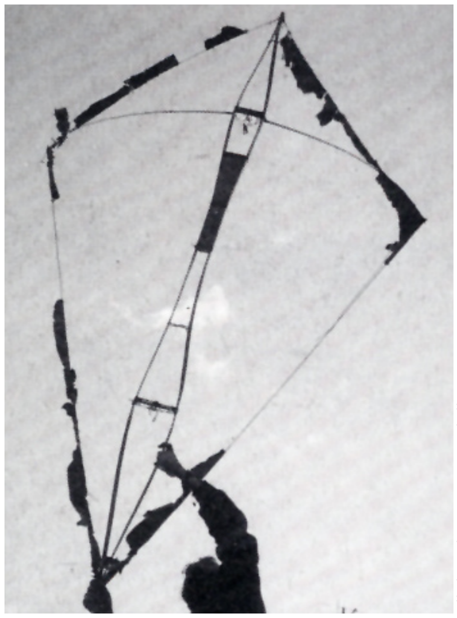
What the world looks like from above: drawing by Nadar.

1860. The first genuinely beautiful and sharply focused aerial photograph is taken by James Black from a balloon 1,200 feet above Boston.

1888. Using an eight-foot Diamond kite, Frenchman Arthur Batut makes the first aerial photograph from a kite, at an altitude of 500 feet over his hometown of Labruguiere. Batut builds a platform on the kite and places on it a handmade box camera with single sheet of film. It is equipped with guillotine shutter and is driven by a rubber band to yield an exposure speed of 1/100 to 1/150ths of a second. The shutter is released by a burning fuse.

1890. Batut publishes a book on kite aerial photography titled *La Photographie aerienne par cerf-volant.* In it, he outlines the uses of KAP for exploration, archeology, military reconnaissance, and monitoring the spread of the dreaded vine disease phylloxera. He points out that with a kite-borne stereo camera, “everyone would be able to have the illusion of a perilous ascent, without running any risk.” Such photographs would make it possible to distinguish details “completely invisible in a simple photograph.”

Arthur Batut



All photos by Beaumont Newhall

Batut’s original kite many years later.

1891. Ludwig Rahrmann is issued a German patent for a photographic system that became airborne when launched by either a large gun or rocket. A camera was fitted into the projectile to be released at high altitude. After photography, a parachute deployed.

1895. Using kites in train and flying at the Blue Hill Observatory, outside Boston, William Eddy claims he is the first person in America to take photographs from a kite. “It requires from six to nine kites seven and nine feet in diameter with a pull of from thirty to sixty pounds to lift the camera and frame to a height of 1,000 feet,” he says. Eddy refines his rig by attaching a string to the shutter release. This not only gives him the means of exposure but steadies the camera. Eddy makes as many as 32 images in a day.

1896. From a roof along Broadway, Eddy photographs a parade in New York City. It is apparently the earliest use of an airborne camera for news photography.

1900. Improving on Batut's work, Frenchman Emile Wenz pioneers high altitude kite photography at meteorological observatories at Nantes, Trappes, and Puy-de-Dome. Flying a train, he achieves an altitude of 5,250 meters (17,220 feet).

1902. Also using a train of kites, Engineer Thilie obtains exceptional 360-degree panoramas of Moscow using seven Zeiss wide-angle cameras. They are mounted so as to cover the entire horizon. An electric shutter release operates only when the apparatus is perfectly horizontal in the sky.

1903. Demonstrating manlifting kites for the British Royal Navy for possible use in military reconnaissance, American Wild West show empresario Samuel F. Cody puts his son 800 feet above the sea off Portsmouth and from that height the son makes hand-held snapshots of ships. They are the first photographs from manned kites.

1903. Alfred Mual is issued a German patent for a rocket camera. Using the system, excellent photographs are taken.

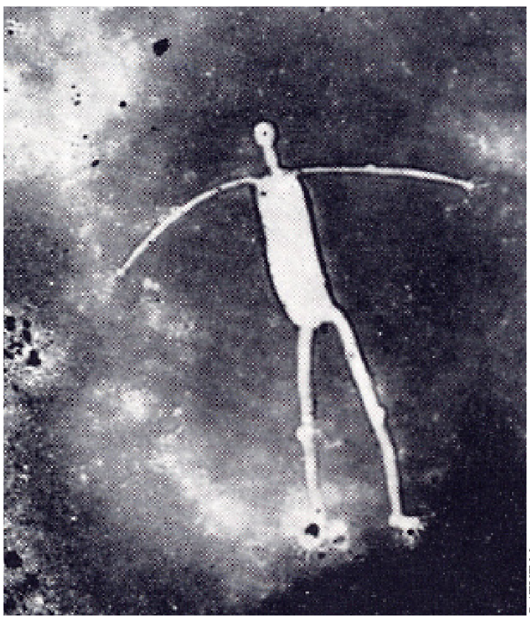
1903. A miniature camera to strap onto a carrier pigeon is patented by Julius Neubronner in Germany. A timer aboard can be set to snap photos every 60 seconds. It is a workable, if erratic, system. Years later, a French magazine comments on the invention: "It is quite natural to see birds becoming photographers at the moment when men are becoming birds."

1906. Having miraculously survived unhurt a fall of 228 feet from a balloon rig, George R. Lawrence turns to using kites for aerial photography. Following the San Francisco earthquake and fire, Lawrence uses 17 kites to dangle his panoramic camera 2,000 feet above a ship in San Francisco Bay to document the devastated city. A four-foot print with great detail from his large camera is titled "San Francisco in Ruins" and when offered for sale to the public becomes a best seller.

1908 onward. Continuing refinement of the Wright brothers' airplane yields a photography platform so accurate as to altitude, so steady, swift, and wide-ranging, it largely supplants balloons, kites, rockets, and pigeons. In '08, newsreel cameraman L.A. Bonvillain shoots motion picture film while flying as a passenger on a Wilbur Wright demonstration flight near LeMans, France. A magazine headlines the single Bonvillain image it publishes: "The First Photograph From an Aeroplane."

1912. Frenchman Pierre Picavet invents a widely used cable-and-pulley system for suspending a camera below a kite. The system is in use today.

1913. Although kite aerial photography has been used in a limited way in archeological work earlier, Sir Henry Wellcome of England systematizes KAP in documenting his digs in the Sudan. The kites use a delayed-action shutter release. Such photograph enables details to come together to form a unified whole, the abstract to become concrete. KAP remains useful to this day in archeological research.



BATUT Museum

An Indian pictograph 30 miles north of Blythe, California. The archeological figure is on such a vast scale-----the man is 167 feet tall----it remained unknown until viewed from the air in the early l930s.

Craig Wilson

Wilson, of Madison, Wisconsin, likes KAP "because I can produce never-before-seen views of familiar subjects. The combination of kite and camera permits me to take my camera to places where only birds and bugs go." He has had 85 magazine covers and more than 1,500 of his images published in magazines, newspapers, calendars, brochures, and on post cards. His recent book *Hanging by a Thread: A Kite's View of Wisconsin* has brought him critical applause and numerous speaking engagements. "Although I KAP on average once a week, I have never lost the sense of play, experimentation, discovery, and adventure in the combination of kite and camera," he says. "My unique vantage points will never be duplicated, exactly. That sense of singularity makes the experience rewarding."

Both photos by Craig Wilson

At a beach celebration of the summer solstice, Wilson achieved this image using a shutter speed of 1/13th of a second, "a relatively long exposure for a handheld camera, much less an aerial shot," he notes. It was a tricky shot. "To avoid blur, the challenge was to trigger the camera when it was hanging very still on the kite line. Since it was so dark I couldn't see the camera well, another problem was aim. I used the reflection of the light from the flames in front of the lens as my guide."

Craig Wilson

Early morning fog rolls in from the Mississippi River and gives historic Villa Louis near Prairie du Chien, Wisconsin, a lovely mantle. To make the shot, Wilson needed good light, good wind, and some fog, and he found all three, "Sometimes it's better to be lucky than good," he says.

KAP and Archeology

Aerial photography----from airplanes, balloons, and not least from low cost, nonthreatening, ready to hand kites----has a special significance in archeology. Seen from the air, details come together to form a unified whole, fragments acquire a pattern, the abstract becomes concrete.

It is difficult to see an overall design in archeological sites, many of which survive only in ruins. Images from the air show how a site is part of the natural environment. They show the landscape, the geographical context, the area covered by a settlement together with its natural resources and the factors that lend it protection.

Occasionally, an aerial view allows us to discover previously unknown monuments that are invisible from the ground.

Archeology is more dependent than other sciences on its ability to examine its objects from a distance. So it is not surprising that aerial research and documentation have had an important impact over the years.

Charles Benton

No telling how many people have been inspired by "Cris" Benton's killer Web site to take up kite aerial photography, but it must be quite a few. A professor of architecture at the University of California at Berkeley, the energetic Benton says he's notorious for being fickle with his interests "but KAP has stuck." Benton adds, "With KAP, you can see details of the landscape you just can't get when you're standing on the ground." His photographs leave him yearning to discover uses and connections between parts of the landscape. "You can't take the photos without them raising questions," he says. "I call it interrogating the landscape." Benton doesn't use a monitor to view the images prior to shooting them. "I prefer to imagine what it would be like if I were up there," he says. "I learn a lot that way."

Winter surf on Drake's Bay.

Decorative flags

All photos by Cris Benton

Very systematic by nature, Benton set out to document Berkeley campus buildings, among them Sather Tower. This shot looking down was a first for him. "It was disconcerting to see your camera rig flying below you at an angle steeper than minus-45 degrees." Benton got the shot. "Since then," he says, "I've developed a locking loop arrangement to secure my 'hangups' to the kiteline more securely in case of a slack line. It relies on tension in the kiteline."

More breaking waves

Old Slide Rule for New Aerial Photo

A Somewhat Odd Trade Offer

Cris Benton

Cris Benton

A professor of architecture at Berkeley by vocation and kite aerial photographer by avocation, Charles Crisp (Cris) Benton maintains one of the most popular KAP Websites going. He uses it to his significant advantage.

After receiving many compliments for the images on his site, Benton decided to take up trading. He offered a signed, original print for a slide rule. Now antiquated but still useful, slide rules have arrived at Benton's campus office ever since. Cris says his collection now totals more than 100 slipsticks. "Many are routine and worth $20," he says, "some are gems and worth maybe $350. None are one-of-a-kind, alas. All of them are industrially produced. The oldest? It dates to 1905."

"The world's most specialized barter system," to use his words, has brought him a wooden rule from Moscow with the interesting characteristic of having all divisions share the single line weight used in its graphic layout. "It's so Russian," he says. "Not well designed and even clumsy in comparison to its Western counterparts, it's still very utilitarian, still gets the job done nicely."

The first slide rule he traded for was ironically very similar to the one he used to illustrate the original offer. It's a compact K. & E. Decilog which Benton often carries around with him and, if not in a hurry, uses to make calculations. "Great fun," he says.

A Sun Hemmi handsomely crafted from bamboo arrived from Japan. Another favorite of his is a five-inch Pickett which arrived in its original, unopened package with leather pouch, instruction manual, and guarantee certificate enclosed. At the other end of the scale is a plastic Pickett training slide rule with the original price of $1.95 on the box. The rule came with a certificate crediting full purchase price toward the acquisition of a "professional" slide rule.

Benton says that for three centuries slipsticks were used by large numbers of people around the globe as their personal calculator of choice. "That world changed with the invention of the microprocessor and subsequent introduction of pocket calculators in the late 1960s," he says. "These events were to slide rules what the giant asteroid was to dinosaurs."

As owners of slide rules acquired the latest Hewlett-Packard calculators, slide rules became objects of limited practical use. "But they were too nice to throw away," says Benton. "Hundreds of thousands were probably retired to the back of drawers. I asked myself, 'So where are they now? Still in the drawer? Gone to live with the missing socks?'"

It was then he conceived his unusual barter plan. Unlike fountain pens, which Benton, being an architect and finding them useful in his work, also collects but which have a large and loyal----and in some cases monied----group of collectors around the world, slide rules have lesser cachet and thus the stage was set for Benton's success.

What does he do with his trove of slide rules? "I play around with them in my office at Berkeley, I chat with people about them. I may do an exhibition one day."

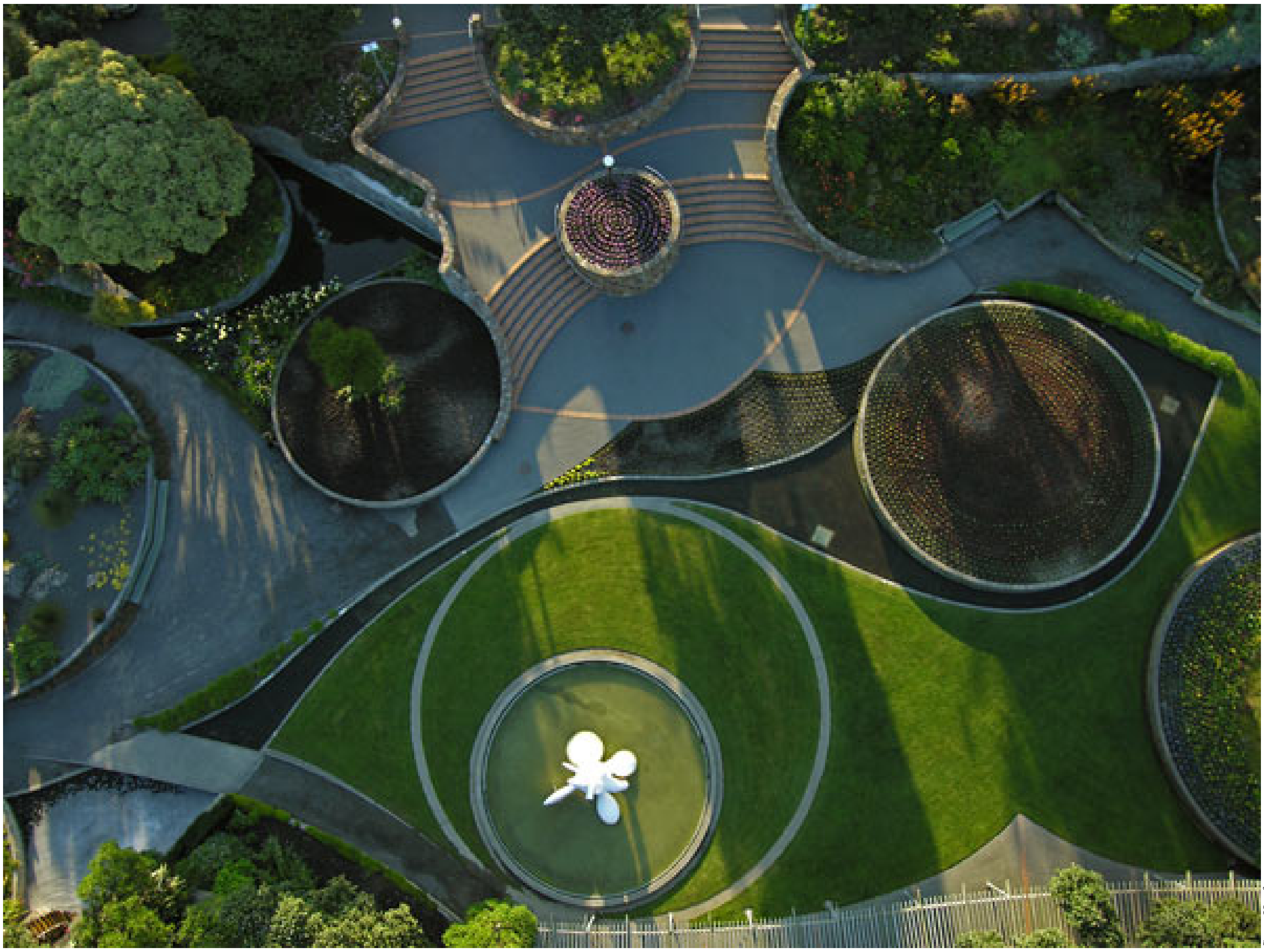
Scott Haefner

A professional photographer and Web designer living in the San Francisco Bay area, Scott Haefner began taking kite-lofted aerial photographs “to gain a new perspective of our world,” as he phrases it. He shoots primarily landscapes and scenics, using both film and digital cameras. He is widely published in books, magazines, and newspapers. With support from the Drachen Foundation, Haefner in spring 2006 on the 100th anniversary of the San Francisco earthquake approximated the famous George Lawrence *Ruins of San Francisco* panoramic photograph from an offshore boat. Haefner suspended his camera and positioned it so as to capture the view Lawrence did. The resulting photograph was a triumph.

Both photos by Scott Haefner

Here Haefner is testing to make sure the shutter for his fisheye lens is being triggered by radio control before letting the kite rig fly. Note the camera hanging from the kite line in the shadow at the center. For a look at his striking 360-degree virtual reality panoramas taken from a kite, bring up his Website at http://www.the haefners.com/kap/

Scott Haefner



While working and traveling in New Zealand, Haefner discovered sunken gardens in Napier, created after a devastating earthquake in l931. "The rebuilt city sprang back to life clad in Art Deco," he says, "making it an interesting modern day destination." What pleases Haefner about the image is its array of circles, lines, and textures, all in the same shot. "What distinguishes KAP images from ordinary shots are these patterns that emerge from above, but I don't usually capture so many different examples in a single photograph, " he says.

4 Kites for Different Winds

Scott Haefner is pleased to discuss the kites and equipment he uses in making his aerial shots, as follows:

The four kites are a Rokkaku, Maxi-Dopero (keeled Double Pearson Roller), Sutton Flow Form 30, and Sutton Flow Form 16. Fuzzy tails add stability to the Flow Forms. He uses 250 meters (760 feet) of 250-pound test line on a Halo spool. Leather gloves protect his hands. He employs a Picavet-style suspension rig, camera rig, radio control transmitter to snap shutter, canvas bag with chargers and spare parts, tool bag, carabiner (or snap-link) plus webbing for tying off the kite. He employs either a Nikon Coolpix 8400 digital or Nikon D80 DSLR camera. The latter has better image quality but is much heavier. He sometimes uses a Nikon FC-E9 fisheye lens.

Why the four kites? Haefner explains: "The classic Japanese six-sided Rokkaku fighter kite has become my favorite. For a framed kite, it is quite easy to set up. It is versatile, allowing me to lift my camera in the widest range of typical wind speeds, including relatively light breezes. In my experience, if it will fly at all, it has sufficient pull to lift my gear.

"In contrast, my soft Flow Forms (modified Parafoils) are notorious for being able to fly in a given wind but unable to lift a camera. Another thing I like about the Rokkaku is that it has a high flying angle, allowing me to make shots in tight spaces. Although it is often used as a fighter kite in air battles with other 'Roks, a Japanese tradition, the Rokkaku, surprisingly, provides a very stable platform."

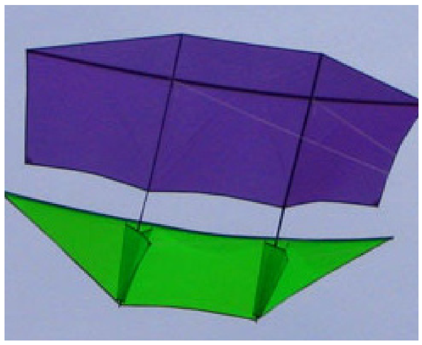
Haefner continues: "The Maxi-Dopero was conceived by fellow kite aerial photographer Ralf Beutnagel, of Germany, especially for KAP work. Like the Rokkaku, it has a high flight angle, often advantageous. An excellent low-wind flier, it provides enough lift to raise my camera in surprisingly low winds. However, I only use it when other kites don't suffice because it is relatively complicated and time-consuming to set up and take apart.

"My two Flow Forms are identical except for size: the smaller one is 16-square feet, the larger one 30. I generally fly the larger one, but sometimes in a real breeze I use the smaller one. Being completely soft, the beauty of the Flow Forms is they really pack down. Both fit in my daypack with my other KAP gear. And they are easy to set up and to launch. Using one of the Flow Forms, I simply take it out of the bag, unroll it, and let the wind catch the sail. Flow Forms are so stable they would be boring to fly for recreation. The Flow Form does occasionally dive down and sideways, but so far I've been able to cope with this aberration and avert disaster. A fuzzy tail is a must for added stability. Flow Forms require more wind than framed kites, which can be an advantage or disadvantage relative to the Dopero and Rokkaku.

"I've calculated the working wind range for each of the four kites. Here are my figures: Dopero 4-11 mph; Rokkaku 5-18 mph; Flow Form 30 8-20 mph; Flow Form 18 15-30 mph. Just because a kite can fly in certain wind conditions, though, doesn't mean it's ideal. For example, in a steady 18 mph breeze, I could fly the Rok or either Flow Form. But 18 mph is at the extreme upper range of the Rok, leaving one of the Flow Forms as the better choice. I always choose the 'least' kite for a given job, meaning one that is at the lower end of its range. So in the case of the 18 mph wind, I'd choose the Flow Form 16 because it will be easiest to manage."

Flow Form

Rokkaku



Maxi-Dopero

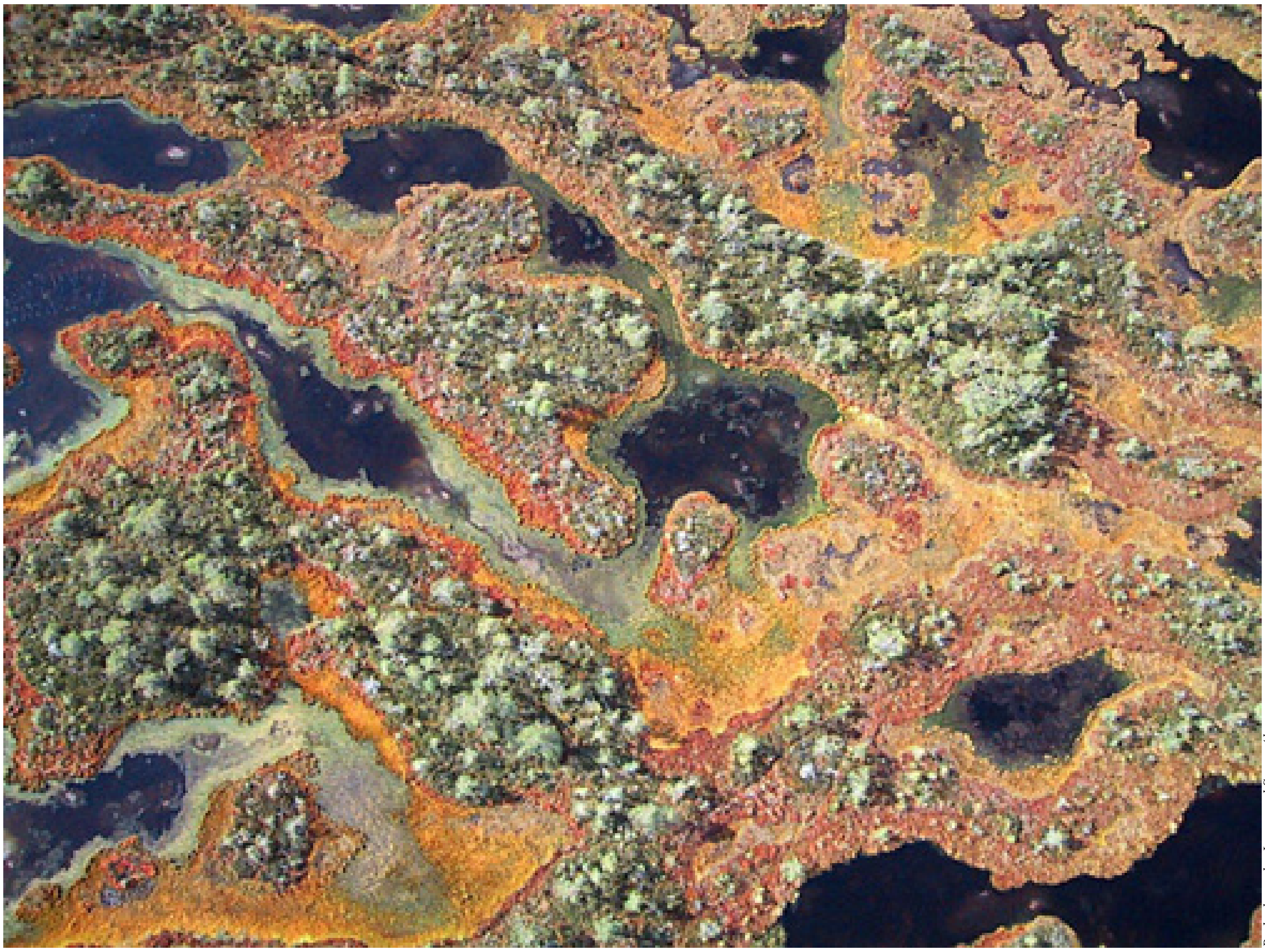
Talking About Kites

"The South Pole, where I worked on a neutrino detector project, killed one KAP camera with cold, and nearly did in another. Since then, I've dropped three cameras, including a video camera that filmed its entire fall, but it landed in deep lawn and it still works. I use the falling movie in my high school physics classes."----Eric Muhs

"KAP has been a wonderful creative outlet for me. Through photography and the website, I meet people from all over the world. I've had serious conversations about flying kites on Mars and mapping the breathing patterns of manatees."----Cris Benton.

James and Susan Aber

Both of them earth science teachers at a state university in Kansas, James and Susan Aber are a husband-wife team that uses kite aerial photography for diverse educational, scientific, commercial, and esthetic purposes throughout the U.S. and in several countries of northern Europe. Devoted KAPers since 1996, the two have been using only high-resolution digital cameras since 2005. Their kites are large Rokkakus and Flow Forms. "We attempt to keep our radio-controlled camera rigs as simple, light, and robust as possible in order to be successful every time we undertake KAP," says Jim. He adds: We have worked on subjects ranging from archeology, to historical monuments, to water resources. Our special interest focuses on landscapes, especially wetland sites----bogs, marshes, lagoons, and shores. The interplay of land, water, and vegetation leads to dramatic colors and patterns that are impossible to see on the ground or from high-flying aircraft. Low-height KAP provides a unique vantage point to acquire images of these natural wonders."



Both photos by James and Susan Aber

This elegant image of an Estonian bog in autumn won the Abers first place in a National Science Foundation photographic contest. "Taking pictures, combined with extensive traveling, is most satisfying to my wife and to me both personally and professionally," says James Aber.

James and Susan Aber

Looking like a bunch of dead fish, juvenile elephant seals are captured on film by the Aber team. The scene is Point Piedras Blancas, California. Note that the kite rig is so non-intrusive the seals are in no way alarmed, or even alerted.

What the Photographers Had to Say

"Cropping is the process of reframing a picture to strengthen the overall composition. It won't cure bad exposures, poor lighting, or out of focus images, but it can cure out-of-level photos, and it can visually strengthen shots that were poorly aimed. Cropped photos may not win any awards, but they move images from the category of snapshots into the realm of professionalism." ----David Hunt

"The overwhelming number of e-mails I receive are positive. I only got one out of hundreds that has been derogatory, and that simply said, 'Man, you are crazier than me'"----Simon Harbord.

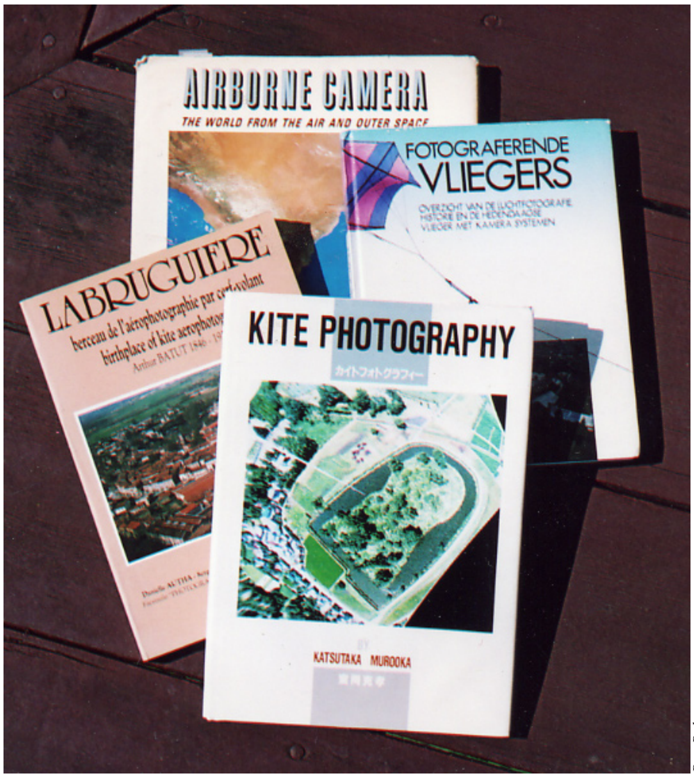
"Kite aerial photography is a form of remote sensing----collecting information about an object from a distance. Photography from kites is, in fact, one of the oldest forms of remote sensing. The images taken from above the surface of the earth gave new perspectives for how people visualized the world, both from practical as well as aesthetic points of view."----James Aber

Select Bibliography

The Aerial Eye, an international journal for kite aerial photographers, published by the American Kitefliers Association l994-99. Useful science and art. All 18 issues, including invaluable index, are available on compact disk for $30 postpaid anywhere in the world. Contact Brooks Leffler at Post Office Box 34, Pacific Grove, CA 93050. "Under the editorship of Leffler, this magazine was so good," comments expert Peter Bults, "it appears to have drained the worldwide KAP user community of ideas in its day and run out of material."

Newhall, Beaumont. *Airborne Camera: The World From the Air and Outer Spa*ce. New York l969. Remarkable photos and prints, sensitive and authoritative text by the former curator of photography at the Museum of Modern Art, New York. Not exclusively about kite aerial photography.

Autha, Danielle and Negre, Serge et al. *Labruguiere: Birthplace of Kite Aerophotography*. Aveyron, France 1988. A tribute to Arthut Batut, 1846-1918. Unique early KAP photos, 54 of them aerial shots by Batut himself and friends, half showing Labruguiere where Batut lived and worked. Batut's equipment is nicely documented. Text in both French and English.



Ben Ruhe

Negre, Serge. *Vu du ciel* (Eye in the Sky). Labruguiere 1999. Text in both French and English. Describes author's fascination with aerial photography and gives details on kites and camera rigs. Includes a collection of Negre photographs from the town of Labruguiere, home of pioneer Arthur Batut, and shots from Negre's Arctic expeditions.

Wilson, Craig. *Hanging by a Thread*: *A Kite's View of Wisconsin*. 2006.

Volgers, Gerrit Bart. *Tersschelling in Vliegervlucht*. 2006. Documents the author's home island Terschelling in the Netherlands. 67 aerial photos and a map showing location of shots. Dutch text.

Cottrell, Mark: *Kite Aerial Photography*. 1987. A now somewhat dated, spiral bound book with just one photograph-

---on the cover----and typewritten pages as text. Hand-drawn diagrams. Cottrell gives very knowledgeable advice on a variety of technical topics. Gives a good feel for what physical factors affect kite photography and what to expect.

Fosset, Raoul: *Aerial Photography by Kite*. Seattle 1994. 13 pages. Something like an updated supplement to Cottrell's book.

Hanson, Carl: *View From a Kite: Kite Aerial Photography, Including How to Attach a Camera to a Kite and Take Stunning Aerial Photographs*. 2001.

From the start, kite aerial photography and the other aerial types of image-making have inspired artists. A photograph of the Eiffel Tower in Paris provoked artist Robert Delaunay to make this handsome, partially abstracted paiinting in l909.

De Beauffort, Geoffroy and Dusariez, Michel: *Aerial Photographs Taken From a Kite*. 1995. A legacy of the Kite Aerial Photography World Association (Kapwa), founded by Dusariez in l985. The first 93 pages are reprints of material that appeared in Kapwa's quarterly magazine published over eight years. Helpful sections devoted to such subjects as: Which kite? Which camera? How to trigger the shutter? Well illustrated. The last 40 pages are a translation of Arthur Batut's 1890 treatise on aerial photography, a fascinating view of the early days of kite-lofted photography.

Murooka, Katsutaka: *Kite Photography*. Tokyo. Hardcover.A picture book. Mainly Japanese text, some English. In his photos, Murooka investigates architecture, the environment, flora and fauna, geology, the ocean, even sporting events. His kites, both Japanese style and Westernized models using ripstop and carbon fiber, include an inflatable Flowform in the shape of a traditional Japanese Yakko kite. Murooks spreads the work about KAP through extensive international travel. Murooka published a second KAP volume titled *A Hand-Made Satellite: Kite Aerial Photography.*

De Ruijter, Gerco: *Gerco de Ruijter*. 80 pages, 60 of them in color. In Dutch. Available in English translation. Magically beautiful images of beaches and other landscapes. De Ruijter is a professional kite aerial photographer and has exhibited widely.

Jebwab, Gaspard and Clinckemaille, Michel: *Espaces naturels de Belgique a vol d'oiseau*. 2004. In French. Three natural spaces photographed from a kite in all four seasons.

Clinckemaille, Michel: *La Belgique vue du ciel*. 2001, revised and expanded in 2003. In French. 100 major Belgian sites photographed from a kite.

Velthuizen, Nop and Van der Loo, Gerard: *Fotograferende Vliegers, etc.* (*Picture-taking kites; overview of aerial photography, history and today's kite with camera systems*.) 1988. Heavily illustrated. Text in Dutch.

Becot, Christian: *Photographie Aerienne Avec Cerf-Volant*. Tourlaville, France 1995. In French. Useful KAP techniques explained via text and illustrations.

Andrea Casalboni

After almost 20 years of KAP and more than 6,000 images taken during that period, Andrea Casalboni, of Ravenna, Italy, remains partially unreconstructed. He uses digital for big format prints, but rejects the help of radio-controlled video in choosing when to shoot because he likes to imagine the shot he is making. "I have more feel for the subject that way," he says. "My experience allows me to put the camera on the right point, while not disturbing the subject. KAP is all about having a close feeling, an affinity, with the subject." Casalboni has traveled and exhibited widely. He has won many prizes. He feels that 70 percent of KAP is nature and that 30 percent is the art contributed by the photographer. "Good photos are not easy to obtain," he emphasizes. "It takes many shots to get one good one." His current focus is shadows, which are always ephemeral. Either the subject moves or the sun does. A shadow image can never, ever be exactly repeated, he notes.

Both photos by Andrea Casalboni

An example of the mystery posed by shadows is illustrated in this shot by Casalboni, where the four-meter tethered beach ball is studied by two 15 meter trilobite kites as reflected only in their shadows. Casalboni lofted a Canan Rebel X camera fitted with wide angle lens to achieve this odd, compelling image.

Andrea Casalboni

Both photos by Andrea Casalboni

Above, another Casalboni conundrum. His kite-lofted Canon G6 camera shows a kind of mystery object in flight. Then its shadow gives the explanation----it's nothing more than a spinning circular kite with decorative spider at its center. Right, a salt rendering field near Ravenna achieves an attactive geometrical texture because of mineralization.

Katsutaka Murooka

Holder of a master's degree in art, Murooka, of Tokyo, took up KAP as a release from his job teaching architectural drafting. It also led him to travel widely, spreading the word about the hobby. Needing the most stable platform in the sky for his photography, experimentation has shown him the Parafoil best suits his needs. It flies at a high angle and easily lifts a 4 ½ pound camera rig in a decent wind. The kite doesn't break and packs down for transportation. Although kites are a means to an end for Murooka, his handmade ones are of exceptional merit, well made, handsome, functional. Murooka favors a single lens reflex camera shooting 400 ASA film at a shutter speed up to 1/1,000th of a second. He mostly uses a wide-angle lens and sometimes a fisheye. Photos are made via radio-control. Servo mechanisms enable him to control the camera's rotation and varying downward angles. Using KAP as a research tool, Murooka has photographed the environment, geology, flora and fauna, the ocean, even sports projects. He has photographed underground dwellings in China, a savannah in Peru, a Japanese woman climber attempting Mount Everest, a landmine field in Cambodia. He has done archeological documentation in Akoris, Egypt, and Pompeii. He has published two books on his work. Not surprisingly, he is chairman of the Japan Kite Aerial Photography Association. Murooka's ambition is to mix kite photography with other disciplines to attain interesting new syntheses. As an example, he wants to study air pollution by taking photos and also researching atmospheric temperatures, humidity, wind pressure, wind velocity, even pollen distribution.

Both photos by Katsutaka Murooka

Because KAP permits shots as low as 50 feet, the tight perspective sometimes makes low level shots, with kite line rising up from ground, notably different, charming, and fun.

Katsutaka Murooka

Murooka managed a few shots of the pyramid at Giza before security guards chased him away. At right, he launches into swarming black-tailed seagulls in a bird sanctuary on Kabu Island in Aomori Prefecture, as part of a Japanese government research program. Below, his Canon single lens reflex camera with 16 mm lens, flown off a big Delta, captures a Peter Lynn Mega Moon kite in flight in Japan. The Moon, in three flag versions----Kuwaiti, American, and Japanese-----is the reigning world's largest kite at 1,000 square meters.

All photos by Katsutaka Murooka

Harald Prinzler

An industrial electronics engineer from Schlangen, Germany, Harald Prinzler took up KAP in the early 1990s and soon became a convert to Flow Forms as aerial platforms. He invented a variation of the Flow Form and has shared it worldwide via his Web site. Prinzler does not use direction control for his camera rig, preferring to use his imagination in pointing the camera. He says he likes it that way----more exciting.

Both photos by Harald Prinzler

A classic subject for kite aerial photography is sand sculptures on the beach during summer vacation. Here Harald Prinzler documents a lazy family afternoon in Denmark with his Leica Z2X. The sculptures are ephemeral, washed away with the high tide.

Oscar Frey

Sally Mizroch

An important Drachen Foundation grantee, Frey is using KAP to assist his research in identifying whales and documenting their behavior. A marine biologist and professional photograph by professions, Frey has been studying whales for 20 years in the San Ignacio Bay of Baja, Mexico, and elsewhere. Frey uses a state-of-the-art camera rig consisting of a Nikon D70 with wide angle and fisheye lenses so as to cover as many mammals in as much area of the water as possible. Under tutoring from Foundation staff, Frey has become KAP sufficient----from setting up to taking down and everything in between. Among other aspects of his research, he focuses on the impact of humans on whales. Flying his kite downwind, Frey can put his camera right over a whale and document any intrusion on it by the large, careless tourist boats that come calling daily. These large vessels are not permitted to come closer than 100 meters, but often do. Using Frey's images, the Foundation has worked with Mexican officials to save the California gray whales and humpbacks and other species from this potentially dangerous harassment. But note that the much smaller, responsibly piloted boats used for research actually attract whales who come up to the side to be scratched and petted by the scientists.

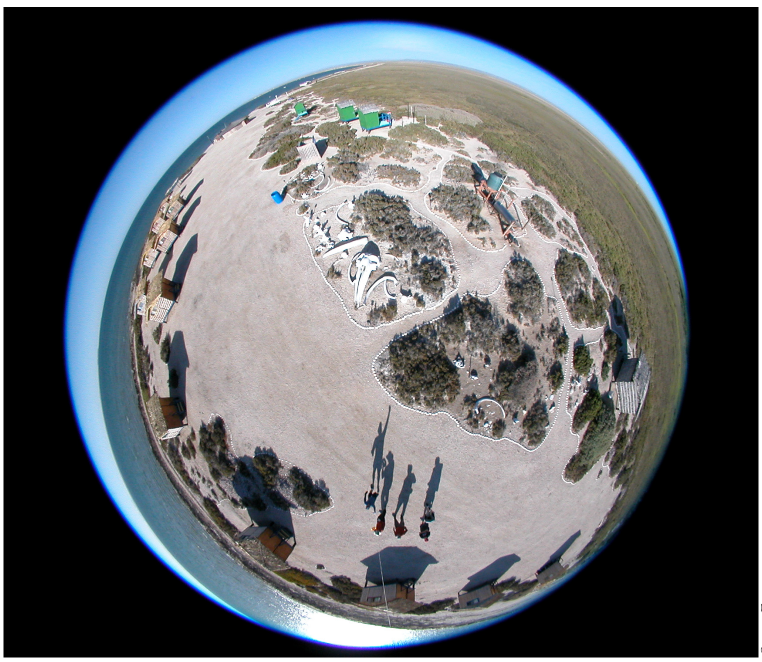
Oscar Frey

Being social creatures, mother (left) and calf gray whales mill around Oscar Frey and assistants in a research boat. Curiosity and the desired to be scratched apparently draws them. Highly intelligent, the whales often turn sideways so they can eye the people in the boats. The mother whale measures some 30 feet in length, the calf some 7 feet. Whales eat microscopic plankton so humans offering them food is not an issue. At the right, two Drachen Foundation staffers and driver proceed with a videotaping of the giant mammals.

Jose Sainz

The Drachen Foundation fields its A Team (there is no B Team) in the study of San Ignacio Bay whales. From left, Oscar Frey, Jose Sainz (flying the kite which made this photo), Scott Skinner, Ali Fujino, and Matt Stubbs. Frey is the head researcher, Sainz a Drachen board member, Skinner president of Drachen, Fujino director, and Stubbs staff videographer. Whale bones litter the beaches of the huge bay and this set from a 35-footer is decorated with an Explorers Club banner carried by Fujino and Stubbs, members of the prestigiouos New York society, as visual recognitition of the important scienfic study being carried out here. The yellow banner, "Investigation in Progress," is Frey's own visual proof of Mexican government backing.

Because the nearest city is more than four hours away by boat, scientists and whale-watching tourists at San Ignacio Bay overnight at Camp Kuyima. Only licensed operators are permitted to bring visitors to view the marine giants. Camp Kuyima is bare bones----note huts to left and top right----and leaves a light footprint behind. Compost toilets are used, all water is trucked in, waste is trucked out. It's sustainable tourism in action, benefiting the public and the whales.



Oscar Frey

A Note to the Reader

Dave Lang, of Seattle, a member of the Drachen Foundation's Board of Directors, monitors scientific applications of energy produced by kites.

The following paper is one of numerous approaches being pursued by scientists of international stature.

Laddermill-sailing,

Ship propulsion by wind energy independent from the wind direction!

Wubbo J. Ockels
(chair holder)
AeroSpace Sustainable Engineering and Technology Chair (ASSET)
www.lr.tudelft.nl/asset
Faculty of Aerospace Engineering
Delft University of Technology
P.O.Box 5058
2600 GB Delft
Netherlands

Submitted to the Journal of the International Shipbuilding Progress.

Abstract

The use of large kites in ship propulsion has been getting a growing attention because of the urgent need to reduce the CO_2 production and thus stop the use of fossil fuels. A novel application of ship propulsion by kites is proposed based on a Laddermill apparatus mounted on a ship. Such an apparatus consist of a winch, an electric motor/generator, a kite system (including launch and retrieval) and controlling electronics.
Rather than the traditional sailing by wind force the Laddermill [2] propulsion is achieved by a combination of the production and use of electrical power and the direct pulling force from the kite system. The feasibility of this application is investigated. It is show that when the overall Laddermill to ship thrust efficiency can be made around 50% the resulting speed of the ship becomes practically independent from the wind direction! Such a capability could thus well change the world's seafaring.

Introduction
Kites have been known since thousands of years. Kites have been mainly used for pleasure and as toys. Over these many years kites have shown little development, the shapes and applications basically stayed similar. Recently kites, however, have enjoyed fast development in shape through the use in novel sports such as kite -buggying, -surfing and snow kiting. A logical extrapolation of these sports leads to kites employed as new ship propulsion. The main drive is the reduction of fuel consumption for large ocean going vessels (Skysails, http://www.skysails.com) although joyfull applications can be imagined for recreational use (http://www.kiteboat.com).

Fig.1 Kite system designed by students form the TU delft to propel a container vessel

The enabling technology for the Laddermill [2],[7] is the remote or computer control of the kite [6],[8]. Several simulation have been developed showing the dynamic behavior of a system of a number of kites attached to lines [3],[4],[5],[12]. From these simulations it is obvious that a passive stable system will be hard to design. It is therefore that control of the kites becomes essential. Recently our group has achieved adequate radio control of typical surf kites and has demonstrated the proof of concept of the Laddermill by generating over 1kW of power. [9],[16] The next step will be the Laddermill-ship application discussed below.

The Laddermill principle

The ASSET group at the Delft University of Technology has initiated the Laddermill project in 2003, sponsored by various parties, see acknowledgement below. The Laddermill project aims at the development of an electrical power generator based on the laddermill principle. The original laddermill idea was patented in 1996 (W.J. Ockels, 2001) [2] .

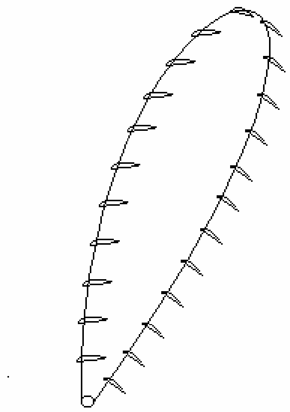


Figure 2. The Laddermill concept where ascending kites are pulling stronger then descending kites and thus drive a ground based generator

The Laddermill is using kites that are connected by a cable to a ground station, which use a real and generator to transfer the wind lifting power of the kites to electrical power. Such can be realized by kites that are connected to an endless loop, see fig 2, or in other ways, such as by a periodic operation of a single line, see fig 3. The ascending kites are brought in a position to create a larger force than the descending kites. Such is achieved by as example a change in attitude (AOA) or by maneuvering (crosswind power [1]) or a change in size of surface (folding) or a combination of these. The Laddermill is presently realized as a one cable system with one or more kites that will be reeled out with high force and reeled in with

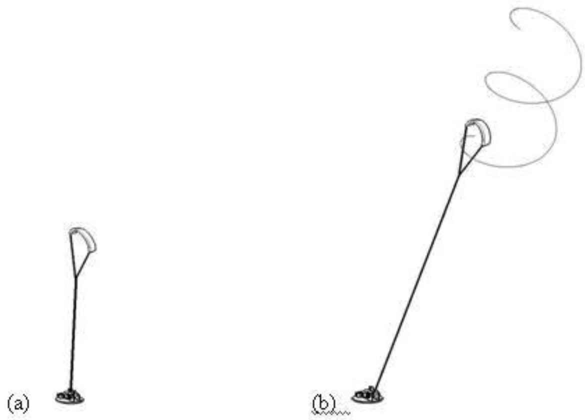


Fig.3 Pumping Laddermill concept. (a) shows the laddermill in the downgoing phase, the tension in the cable is minimized, and (b) shows the upgoing phase where the kite creates maximum cable tension by flying at high speed (crosswind power)

low pulling force. ("Pumping Laddermill") A pumping Laddermill has been build and tested. Various experiments are prepared to be performed using the newly installed "Kitelab", on the roof of the faculty building [18]

Several applications of the Laddermill system are under investigation such as a high altitude power station (up to 9000 m).

Recent studies in our group [13] showed that a two stage pumping laddermill configuration is more practical in this early stage of development and simpler to realize. In this configuration there is an upstroke where energy is produced and a down stroke that resets the apparatus into its original state. In the initial state a large portion of the kite line is wrapped around a drum that is connected to a generator/ motor combination. During the ascending phase the kites are brought in a position to provide maximum tension in the cable. Such is obtained by a combination of an increased angle of attack and a particular flight path. The latter augments the apparent wind and creates so-called crosswind power"[1].

The high cable tension is than subsequently converted into rotary motion of the drum. During this upstroke energy is produced. When all the kite line is rolled off the drum, the kites are kept stationary in the flight envelope and are configured for minimum pulling force, i.e. angle of attack. Now a portion of the generated energy is used to drive the drum and retrieve the kite line. During this phase the apparatus consumes energy, but much less than generated during the upstroke. The Laddermill is now in its initial configuration and ready for a new cycle while there is a net energy surplus.

Once the pumping Laddermill system is developed and experience has been obtained in control and stability, other concept will be investigated. Next to using existing kites or optimizing those for Laddermill use, another approach is also taken. Here the development starting point is the airplane [8]. The controllability airplanes is known and can easily be adapted to the kite application. The challenge for this approach is the lightweight construction and attachment to the cable, with or without bridle lines.

Simple formula's:

From basic principles one can derive the angle at which the Laddermill kites and its connecting cable will be for optimal power production.(see figure 4)

For the sake of simplicity the masses of the kite and cable are ignored.

From the triangle of apparent wind speed V_a, the cable speed V_k and the ship's wind speed V_t which is the vector sum of the wind V_w and the ship speed V_s we have:

$$\frac{V_a}{\sin\beta} = \frac{V_t}{\sin\varphi} = \frac{V_k}{\sin\gamma} \tag{1}$$

Where

$$\varphi = \beta + \gamma$$

$\tan\varphi = \dfrac{c_l}{c_d}$ (=the lift over drag of the kite system)

The aerodynamic forces of the kite system with total surface S will be given as:

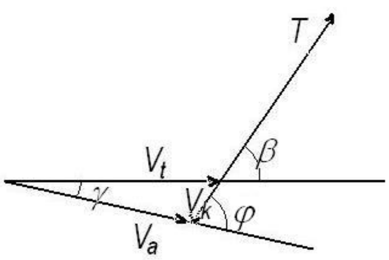


Figure 4, force vectors of an upgoing kite, showing apparent wind and related

$$q = \tfrac{1}{2}\rho \cdot (V_a)^2$$

$$L = q \cdot c_l \cdot S$$

$$D = q \cdot c_d \cdot S$$

$$T = \sqrt{L^2 + D^2}$$

Now the power that the Laddermill kites deliver is given by:

$$P = T \cdot V_k \tag{2}$$

And to optimize this power one needs to maximize the product of tension T and cable speed V_k. The tension results form the aerodynamic force, therefore T is proportional to the square of the apparent wind, thus:

$$P \sim V_a^2 \cdot V_k \tag{3}$$

Using (1) and (3) and the condition for maximum power is:

$$\frac{d(\sin\beta)^2 \sin\gamma}{d\beta} = 0 \qquad (4)$$

Or,

$$2\cos\beta\sin\gamma - \sin\beta\cos\gamma = 0$$

With some rewriting the result is:

$$3\sin(2\beta - \varphi) - \sin\varphi = 0 \qquad (5)$$

(5) shows that the optimal angle for the kite cable is only dependent on the lift over drag of the kite system and can be calculated as:

$$\boxed{\beta = \tfrac{1}{2}\varphi + \tfrac{1}{2}\arcsin(\frac{\sin\varphi}{3})} \qquad (6)$$

In the table 1 a list of L/D values and corresponding beta values are shown. For typical kites this value will be around 50 degrees.

Laddermill Sailing

One very intriguing application is the Laddermill propelled ship which is further elaborated in this paper. In this application the ground station of a Laddermill is place on a ship, through which electrical power is generated. For advanced kites it can be shown that the power generating force is significantly larger than the drag. In that case the ship can sail against the wind. In fact the ship's speed against the wind enhances the wind speed to which the kites are exposed (apparent wind). As the larger part of the corresponding increase in aerodynamic force is generating electrical power rather than drag (high Lift over Drag kite) the ship takes advantage of this phenomena. In other wind directions, the Laddermill kites will next to generating electrical power also pull the ship. The result is that combined ship propulsion can be made more or less independent of the wind direction as shown below.

The use of kites as main ship propulsion method provides a number of advantages over the use of a normal sail fixed to a mast. The main advantage is that the kite can use the higher wind speeds that are found at higher altitudes and that the kite can make maneuvers perpendicular to the wind to increase the apparent wind speed. Both effects increase the maximum forces that are available for ship propulsion compared to classical sailing technique. The heel caused by the wind force be generally less for kites because the cable attachment and thus center of effort will be lower than is the case when the force is due to a traditional sail. The vertical component of the kite pulling force can also assist in lowering the heel by moving the attachment point to lee. In addition to the mentioned advantages, can the Laddermill on a ship continue its electrical power production while the ship is stationary, i.e. being anchored.

The intriguing result of the Laddermill propulsion is that this type of ship propulsion drives ship on wind energy more or less independent of the wind direction. The relationship between the performance of Laddermill sailing and the overall efficiency is developed below.

Using the vectors of figure 2 one can write (we do not consider the side force)[1]:

$$D_s \cdot V_s = \eta \cdot T \cdot V_k - \cos\theta \cos\beta \cdot T \cdot V_s \qquad (7)$$

Where
D_s is the drag of the ship
V_s is the ship speed
η is the overall system efficiency
θ is the relative wind angle to the ship speed direction (in horizontal plane)

The overall system efficiency η is defined as the ratio of net ship propulsion in thrust times speed and the net kite power in cable tension multiplied by the cable speed. The power chain comprised of the kites and cable, the mechanical transfer of the power to a generator, the electric motor and its control and the propeller, including the propeller losses.

Using (7) some calculations where done for a 60 tons sailing ship and 300 m[2] of Laddermill kite system in 20 knots of wind[2]. The ship resistance was taken form the VPP calculations, seen fig 5. The overall system efficiency was taken 20% and 50% respectively, see figure 6.

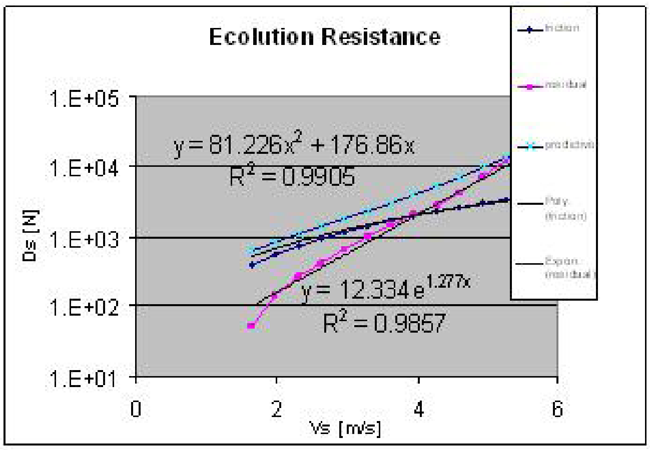


Figure 5, the Ecolution resistance calculation and the derived formula of friction (polynome) and residual (exponential)

[1] Side force is normally compensated by a keel, which acts like a wing in the water. The lift created will induce resistance. As the ship speed is normally higher at intermediate wind angles, this extra resistance is compensated.
[2] S.Y.Ecolution, a schooner type sailing boat, Gerard Dijkstra/Wubbo Ockels design, www.ecolutions.nl

From figure 6 is becomes clear that the ship speed in the upwind directions will strongly depend on the overall system efficiency.

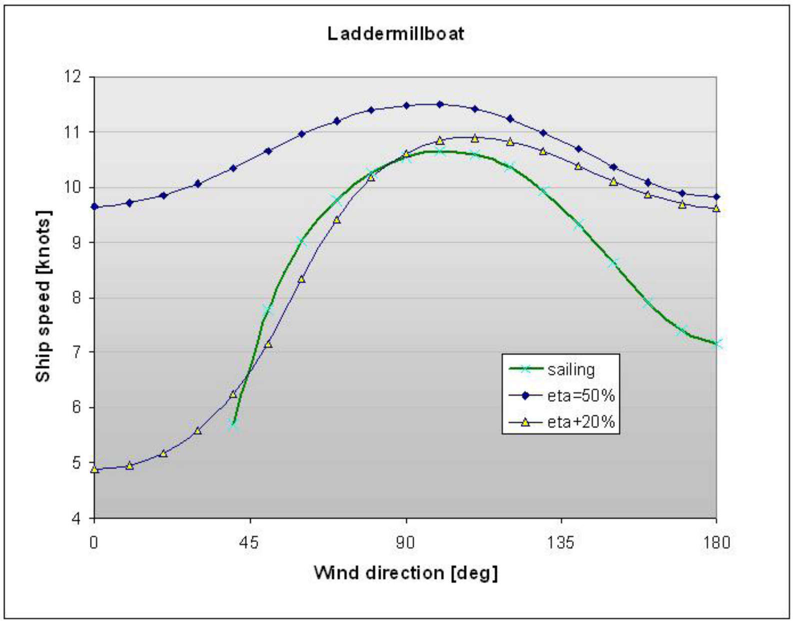


Fig.6 Ship speed as function of true wind angle for a traditional sailing ship (green) and for Laddermill sailing.. For the latter case ship speed is more or less independent of wind direction when the efficiency reaches 50%.

Intriguingly one notices that for η is about 50% the ship will go at the same speed towards the wind as with the wind (down wind) while at intermediate directions its speed is somewhat higher.

Next we will derive a more general consideration for Laddermill-sailing upwind and thus give a more general insight in the feasibility and potential of the Laddermill ship propulsion.

We derive here a formula for the minimum efficiency required as to reach an upwind ship speed that is equal to the downwind speed independent of the ship characteristics.

For the upwind direction we have according (7):

$$D_s \cdot V_s = \eta \cdot T^- \cdot V^-{}_k - \cos\beta^- \cdot T^- \cdot V_s \quad (8a)$$

And for the downwind direction (at the same ship speed):

$$D_s \cdot V_s = \eta \cdot T^+ \cdot V_k^+ + \cos\beta^+ \cdot T^+ \cdot V_s \quad (8b)$$

The $T^{\pm}, V^{\pm}, \beta^{\pm}$ indicate that these parameters differ for the upwind and downwind direction.

To derive the expression for $\beta^{\pm}$ for the Laddermill-sailing case one needs to optimize $\eta \cdot T^{-} \cdot V^{-}{}_{k} - \cos\beta^{-} \cdot T^{-} \cdot V_{s}$ for the upwind case and $\eta \cdot T^{+} \cdot V_{k}^{+} + \cos\beta^{+} \cdot T^{+} \cdot V_{s}$ for the downwind case rather than optimizing the power $\eta \cdot T \cdot V_{k}$ as was done in (6).

Similarly to (5) the derivative of (7) leads to:

$$\frac{\eta}{2}(\sin\varphi - 3\sin(2\beta - \varphi)) - \cos\theta \cdot \sin\varphi \cdot \frac{V_s}{V_t} \cdot (2 - 3(\sin\beta)^2) = 0 \qquad (9)$$

The solutions of (9), i.e. β^{+} and β^{-} for $\cos\theta = \mp 1$, will be different form β_0. Some inspection of the second term in (9) will show that this difference is more for the up wind (-) case than for down wind case (+). Herethe value of β_0 is taken in (8a) and (8b) , because that allows the elimination of the ship related part (left hand side of 8a en 8b). The result would give a minimum effeciency is slightly higher than the minimum obtained by using (9).

Having said this, one can now continue and subtract (8a) and (8b) and eliminate the ships part.

We define the ratio of the ship speed and wind speed:

$$f = \frac{V_s}{V_w}$$

And thus:

$$\frac{T^{+}}{T^{-}} = \left(\frac{V_t^{+}}{V_t^{-}}\right)^2 = \left(\frac{V_w - V_s}{V_w + V_s}\right)^2 = \left(\frac{1-f}{1+f}\right)^2$$

$$\frac{V_k^{+}}{V_k^{-}} = \left(\frac{V_w - V_s}{V_w + V_s}\right) = \left(\frac{1-f}{1+f}\right)$$

Subtracting both (8a) and (8b) with $\beta^{+} = \beta^{-} = \beta_0$ now yields:

$$0 = \eta \cdot V_k^{-}\left(1 - \left(\frac{1-f}{1+f}\right)^3\right) - \cos\beta \cdot V_s\left(1 + \left(\frac{1-f}{1+f}\right)^2\right) \qquad (10)$$

The ratio V_k^{-} and V_s can be written as (using (1)):

$$\frac{V_k^{-}}{V_s} = \frac{\sin\gamma}{\sin\varphi} \cdot \frac{V_t^{-}}{V_s} = \frac{\sin\gamma}{\sin\varphi} \cdot \left(1 + \frac{1}{f}\right)$$

Substituting this in (9) and some rewriting results in:

$$\eta = \frac{1+f^2}{3+f^2} \cdot \frac{\sin\varphi \sin\beta}{\sin(\varphi-\beta)} \qquad (11)$$

This result (11) is independent on the type of ship and of the speed of the ship. The validity is obviously restricted to a ship speed less than the wind speed.

In the table below the results using (6) and (11) are shown for some practical values of L/D and the ration of ship speed and wind speed.

Minimum efficiency Laddermill ship with Vupwind=Vdownwind

		f=Vs/Vw						
L/D	beta(deg)	0.2	0.3	0.4	0.5	0.6	0.7	0.8
1	29.3	0.78	0.80	0.84	0.88	0.92	0.97	1.03
2	40.4	0.60	0.61	0.64	0.67	0.70	0.74	0.78
3	45.0	0.51	0.53	0.55	0.58	0.61	0.64	0.68
4	47.4	0.47	0.48	0.50	0.53	0.56	0.59	0.62
5	48.9	0.44	0.46	0.48	0.50	0.53	0.55	0.58
6	49.9	0.43	0.44	0.46	0.48	0.50	0.53	0.56
7	50.6	0.41	0.43	0.44	0.47	0.49	0.52	0.55
8	51.1	0.40	0.42	0.43	0.46	0.48	0.51	0.53
9	51.5	0.40	0.41	0.43	0.45	0.47	0.50	0.52
10	51.8	0.39	0.40	0.42	0.44	0.46	0.49	0.52
11	52.1	0.39	0.40	0.42	0.44	0.46	0.48	0.51
12	52.3	0.38	0.40	0.41	0.43	0.45	0.48	0.51

Table 1, the minimum efficiencies needed for reaching up wind ship speed equal to the down wind speed ship speed for various kite quality (e.g. lift over drag ration)

From the numbers in table 1 one can conclude that a typical system efficiency of 50% (green area) would be sufficient for a Laddermill ship to sail at a speed independent of the wind direction.
Such an efficiency will , although large diameter propellers and very efficient electric motors and converters are required, be feasible.

Conslusions

We conclude that Laddermill-sailing is feasible for existing kites (kites with a Lift over Drag ratio of typically > 5) and provides an unequalled potential for sustainable seafaring. The implementation is facilitated by the development of diesel-electric ships, as one can add the Laddermill system to those ships while not impairing the basic propulsion system and its corresponding reliability. Further studies can be undertaken to investigate and map the favorable wind conditions and its predictability.

Recent developments in weather observing satellites (Aeolus, European Space Agency) and weather prediction models will favor the Laddermill sailing concept.

Practical demonstrations:

Using a simple ground station and surf kites, we are planning to demonstrate power-generating capability of several 100's of kW's in the near future. This level seems just right for a 100 tons displacement tourist boat. Negotiations are ongoing with the Port of Rotterdam to start such project, which then will also be the proof-of-concept for the application at larger vessels. The corresponding typical pulling force of the kite is planned around 20000 N which can be reached with winds of typically 25 knots . At altitudes of 100-500 m such wind speeds are very common, also at night when the surface winds tend to lay down. Even for inland trips the Laddermill can provide power and propulsion. When stationary the Laddermill can be used for battery charge and hotel power. Inland restrictions for the kite altitude are mostly 150m. At sea these restrictions relax, although specific cases need to be investigated.

Controllable kites form the enabling technology for wind energy production and ship propulsion by kites. We have developed several electromechanical control mechanisms and are currently testing autonomous control of a kite through a software routine. Once these routines are optimized we can ensure fully automatic functioning of a laddermill. This enables us to realize a test for laddermill-sailing in the near future. The construction of a kite based propulsion that allows a ship to sail straight upwind will hopefully provoke a large interest for kites, kite-sailing and laddermill-sailing.

References

1. Loyd, M.L., 1980, “Crosswind Kite Power”, Journal of Energy, vol. 4, No. 3, pp 106-111.
2. Laddermill Patent Ned. 1004508. Nov. 1996
3. Meijaard J.P., Ockels W.J., Schwab A.L. Modelling of the Dynamic Behaviour of a Laddermill, A Novel Concept to Exploit Wind Energy // Proceedings of the Third International Symposium on Cable Dynamics, 1999, pp. 229-234
4. Delhaes G.M.J., Meijers P., Meijaard J.P., Ockels W.J., van Woerkom P.T.L.M. O-Mill: Study of the behaviour of a Laddermill. Report LTM-1220. Delft, Netherlands: TU Delft, 1999
5. Delhaes G.M.J., Meijers P., Meijaard J.P., Ockels W.J., van Woerkom P.T.L.M. O-Mill: Manual for the program OMILL3. Delft, Netherlands: TU Delft, 1999
6. Ockels W.J. Knowledge status December 1998 and baseline Laddermill test model functional requirements. Technical note TN-O-mill 99/01, ESA: ESTEC, 1999
7. Ockels W.J. Laddermill, a novel concept to exploit the energy in the airspace // Aircraft Design, 2001, No. 4, pp. 81-97
8. Ockels W. J., Gool H. J. van , Laddermill, a novel concept to exploit the engergy in the airspace, European Wind Energy Conference, Nice, 1-5 March, 1999
9. Ockels W.J., Lansdorp B., Breukels J.; The Laddermill Development, Proceedings of the European Wind Energy Conference 2004, London-UK.
10. Lansdorp B., Ockels W.J., Remmes B.; Design and testing of a remotely controlled surfkite for the Laddermill, World Wind Energy Conference 2005, Melbourne, Australia.
11. Lansdorp B., Ockels W.J. Design of a 100 MW Laddermill // Electronic Proceedings of 7th World Congress on Recovery, Recycling and Re-integration, 2005
12. Williams P., Sgarioto D., Trivailo P. Motion Planning for an Aerial-Towed Cable System // AIAA Guidance, Navigation and Control Conference, 2005, AIAA 2005-6267
13. B. Lansdorp, W.J. Ockels; Comparison of concepts for high-altitude wind energy generation with ground based generator, 2nd China International Renewable Energy Equipment & Technology Exhibition & Conference Proceedings (pp 409-417), Beijing, China 2005.
14. B. Lansdorp, W.J. Ockels; Design of a 100 MW Laddermill for wind energy generation from 5 km altitude, 7th World Congress on Recovery Recycling and Reintegration 2005, Beijing China.
15. J. Breukels, W.J. Ockels; Tethered Wing Design for the Laddermill Project, Proceedings World Wind Energy Conference 2005, Melbourne, Australia.
16. LansdorpB., Ockels W.J., Design of a 2kW Laddemill groundstation, Conference on Wind Power Asia, Beijing 2006
17. Mulder J.A., van Staveren W.H.J.J., van der Vaart J.C., de Weerdt E. Flight dynamics lecture notes. Delft: TU Delft, 2006 10. Sedov L.I. A course in continuum mechanics. Vols. 1-4. Groningen: Wolters-Noordhoff, 1971–1972
18. Breukels, J. Kitelab, internal report April 2006

Acknowlegdment

This work is part of the Laddermill project that is sponsored by the Delft University of Technology, the University of Groningen, Gasunie, Fugro, Shell Research, the Town and Province of Groningen.

Appendix, the derivations in the paper (for referee ease, not for publication):

For equation (5):

$$\frac{d}{d\beta}(\sin\beta)^2 \sin\gamma = 0$$
$$2\cos\beta\cdot\sin\beta\cdot\sin\gamma - \cos\gamma\cdot(\sin\beta)^2 =$$
$$\sin\beta\cdot(2\cos\beta\cdot\sin\gamma - \sin\beta\cdot\cos\gamma) =$$
$$\sin\beta\cdot(\sin(\beta+\gamma) - \sin(\beta-\gamma) - 1/2(\sin(\beta+\gamma) + \sin(\beta-\gamma))) =$$
$$1/2\sin\beta\cdot(\sin(\varphi) - 3\sin(2\beta-\varphi))$$

For equation (9):

To maximize $D_s \cdot V_s = \eta\cdot T\cdot V_k - \cos\theta\cos\beta\cdot T\cdot V_s$

$$T = K\cdot V_a^2$$
$$V_a = \frac{\sin\beta}{\sin\varphi}\cdot V_t$$
$$V_k = \frac{\sin\gamma}{\sin\varphi}\cdot V_t$$

$$D_s \cdot V_s = \eta\cdot T\cdot V_k - \cos\theta\cos\beta\cdot T\cdot V_s$$

$$D_s\cdot V_s = \eta\cdot K\cdot\frac{\sin^2\beta}{\sin^2\varphi}\cdot V_t^2\cdot\frac{\sin\gamma}{\sin\varphi}V_t - \cos\theta\cdot\cos\beta\cdot K\cdot\frac{\sin^2\beta}{\sin^2\varphi}\cdot V_t^2\cdot V_s$$

$$\frac{d}{d\beta}(\eta\cdot\sin^2\beta\cdot\frac{\sin\gamma}{\sin\varphi}\cdot V_t - \cos\theta\cdot\cos\beta\cdot\sin^2\beta\cdot V_s) = 0$$

$$\frac{d}{d\beta}\cos\beta\cdot(\sin\beta)^2 =$$
$$-(\sin\beta)^3 + 2(\cos\beta)^2\sin\beta =$$
$$-(\sin\beta)^3 + 2\sin\beta - 2(\sin\beta)^2\sin\beta =$$
$$\sin\beta\cdot(2 - 3(\sin\beta)^2)$$

And from above the derivation of (5):

$$\frac{\eta}{2}\cdot\sin\beta\cdot(\sin\varphi-3\sin(2\beta-\varphi))-\cos\theta\cdot\sin\varphi\cdot\frac{V_s}{V_t}\cdot\sin\beta\cdot(2-3(\sin\beta)^2)=0$$

For equation (10):

$$0=\eta\cdot V_k^{-}(1-\left(\frac{1-f}{1+f}\right)^3)-\cos\beta\cdot V_s(1+\left(\frac{1-f}{1+f}\right)^2)$$

$$\frac{V_k^{-}}{V_s}=\frac{\sin\gamma}{\sin\varphi}\cdot\frac{V_t^{-}}{V_s}=\frac{\sin\gamma}{\sin\varphi}\cdot\frac{(1+f)}{f}$$

$$0=\eta\cdot\frac{\sin\gamma}{\sin\varphi}\cdot\frac{(1+f)}{f}\cdot(1-\left(\frac{1-f}{1+f}\right)^3)-\cos\beta\cdot(1+\left(\frac{1-f}{1+f}\right)^2)$$

$$0=\eta\cdot\frac{\sin\gamma}{\sin\varphi}\cdot\frac{((1+f)^3-(1-f)^3)}{f}-\cos\beta\cdot((1+f)^2+(1-f)^2)$$

$$0=\eta\cdot\frac{\sin\gamma}{\sin\varphi}\cdot\frac{(6f-2f^3)}{f}-\cos\beta\cdot(2+2f^2)$$

$$\eta=\frac{\cos\beta\cdot\sin\varphi\cdot(1+f^2)}{\sin(\varphi-\beta)\cdot(3+f^2)}$$