NAIP From the Contractor's Perspective ("Life in the Fast Lane")

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Introduction

The government project personnel at the USDA Aerial Photography Field Office (APFO) in Salt Lake City are very knowledgeable about the contractor's side of National Agriculture Imagery Program (NAIP). Since many NAIP partners are less knowledgeable about the challenges that confront contractors on an annual basis, this paper will hopefully shed some light on this aspect.

As a contractor on the NAIP effort since 2002, we at Surdex Corporation are intimately familiar with the challenging aspects of acquiring and processing large amounts of NAIP imagery in very short timeframes. Much of the following discussion addresses the most critical phase of the program—acquisition. As we all know, nothing happens without "imagery in the can"—or, rather, on the hard drives!

NAIP Acquisition

Surdex has never failed to acquire a project area—something we are proud of, but also have never taken for granted—Mother Nature and Mr. Murphy are indeed fickle and at times seem to work overtime just for us.

All imagery captured for the NAIP fall under specifications that are both general in nature and also specific to the sensor employed for acquisition. The NAIP specifications allow for acquisition using aerial film cameras, aerial digital sensors, and satellite systems. Since the demand for "4-band" imagery is increasing, the acquisition is primarily performed by aerial digital sensors. In 2009, 29 of the 32 NAIP states will be acquired with digital cameras—only three are being acquired with film systems.

Surdex Cessna 441 (Conquest) Aircraft and Installed Digital Sensor (DMC)

Until a few years ago, the predominant use of film resulted in acquisition specifications built around the NAPP (National Aerial Photography Program) stationing system devised by the USGS decades ago – which requires exposures at the center, top, and bottom of each DOQQ from an altitude of 20,000′ above ground (based on a standard 6″ focal length mapping camera). The original DOQQ program called for the orthorectification of the DOQQ-centered photography and was not necessarily focused on what is now referred to as "mosaicking". The NAPP stationing was abandoned a few years ago and contractors are now free to acquire data using "custom" flight plans. The reasons for this change were multiple:

1) With the increasing use of digital sensors with varying format and acquisition method (frame vs. pushbroom), the NAPP stationing was not applicable.

2) The government listened to the contractors as all tried to control the ever-increasing costs of acquisition. Aviation fuel, once a small part of our variable acquisition cost, is now a large part of the variable cost. Following NAPP stationing was inefficient. For example, in the northern states the convergence of the meridians of longitude results in excessive side laps of over 45% (25-30% is the standard for mapping). Secondarily, the accompanying 20,000′ flight altitude restriction was partially based on the scanning of aerial film at 25 microns (an old guideline), whereas new scanners could easily produce even higher quality at 12-15 microns. Thus, aircraft could fly higher to achieve the same product resolution. Allowing the contractors to fly higher and using more efficient flight plans increased acquisition performance and decreased flight time. This has led to an overall reduction in acquisition resources, based on flight hours, of 30-40%.

3) In parallel, the requirement to mosaic the imagery made the DOQQ-centered exposures a moot point. Technicians are now free to use the best view from each overlapping exposure to counter sun illumination effects, specular reflection, and rugged terrain. Using mosaicking, an improved product has resulted.

The changes in the specifications have resulted in the increasing use of high-performance, pressurized twin-turbine aircraft capable of flying above 35,000′. The higher the flying height, the greater the individual exposure covers, and the less acquisition time that is needed. The use of twin-piston aircraft, which are restricted to lower altitudes, is diminishing. The favored aircraft are much more expensive ($2M for a turbine aircraft versus $300-500K for a piston aircraft), but require fewer acquisition hours. On average, this washes out the higher cost of ownership and operation. The advantage to NAIP is that fewer aircraft are required and the ability to perform acquisition in short time frames over very large areas has improved acquisition performance.

The quick transition to aerial digital sensors has resulted in better products, but has also resulted in large capital investments by the contractors. A digital sensor costs ~$1M as opposed to a new aerial film camera at ~$400K. Additionally, a digital sensor has a projected life span of 4-7 years compared to the 15-20 years of a film camera. Though mapping companies handle finances in different ways, the net result is that the annual cost of ownership of a digital sensor is roughly equivalent to purchasing a new aerial film camera each year! The allocated costs of a camera are based on its utilization – quite literally, the more a camera is used, the lower the cost to the end-user. Simply stated, the hourly cost is the annual fixed

Color and CIR NAIP DOQQs. *Minnesota, 2008*

cost divided by the anticipated hours of use. Using $400K as an annual cost, if 400 hours of utilization result, the hourly cost of the camera is $1,000. Contractors involved in the NAIP are essentially encouraged to purchase digital cameras. Since most imagery has been historically acquired during the leaf-off periods (spring), the additional use of the systems during the traditionally slow summer months has helped increase utilization and lower costs to the end-users. Most agree that the NAIP is the single most driving factor in the quick transition to digital cameras by the mapping profession.

Beginning in 2009, the decision was made to convert from relative accuracy (judged against "controlled imagery") to absolute accuracy for all current and future project areas. Absolute accuracy is currently specified as ±6 meters, CE95. This has put an emphasis on the collection of ABGPS and often IMU data, coupled with ground survey points used to control and verify the accuracy of the products. The use of ABGPS/IMU is an inferred requirement stemming from cost-effectiveness – it is not a stated requirement of the NAIP.

A summary of the basic acquisition specifications:

1) Acquisition of imagery at resolutions better than 1.05 meter to support the production of 1 meter DOQQs.
2) Full stereoscopic imagery collection over the DOQQ coverage. This supports multiple ancillary uses, the modification of the elevation surface (if required) to achieve the absolute accuracy, and the ability to pick-and-choose the best view of the terrain from overlapping images. The best possible USGS National Elevation Dataset (NED) is currently the specified surface for the NAIP.
3) Collection within "season windows" in each state that are aligned with the peak growing period of the most important crops. In some states, this includes multiple season windows to achieve the necessary coverage supporting the administration of the Farm Compliance programs. Windows vary in length from a month to several months.
4) DOQQs cannot contain more than 10% combined cloud/cloud shadow effects. Given the nature of acquiring from higher altitudes, the existence of cloud/cloud shadow effects in the final products is uncommon. Mosaicking has also helped here – removing a small cloud by inserting an area from an overlapping image.
5) DOQQs cannot contain standing water. In addition, cases of specular reflection that obscure the shoreline of bodies of water must be replaced with an alternative view from an overlapping image. In reality, this only happens with very high sun angles. Even working in 2008 in the Land of 10,000 Lakes (MN), we had very little interference from this.
6) A sun angle of at least 30°.

The Surdex Team currently exclusively uses the Intergraph DMC digital camera. This large-format frame camera simultaneously collects panchromatic, color (red, green, blue), and near infrared imagery at each exposure station. Each exposure results in ~500MB of image data capture. The geometry of the camera dictates that we fly no higher than 10,000 times the desired resolution (GSD, or ground sample distance). Therefore, for 1 meter imagery, we fly no higher than 10,000 meters (~32,000'). Note that this is expressed as above ground level (AGL), defined as the clearance above the lowest feature within the coverage of each exposure. For example, in Missouri the average ground elevation is ~1,000' MSL, and thus we fly no higher than 32,000 + 1,000 or 33,000' MSL.

Mission plans are developed for each project area based on a number of parameters. Specific to the DMC system, this amounts to:

1) Flying heights of no more than 32,000' AGL.
2) Full stereoscopic coverage over the entire project area.
3) Nominally based on at least 60% forward lap and 30-35% sidelap – varying based on the ruggedness of the area.
4) Additional exposures at the ends of each line to accommodate ABGPS integrity.
5) Planning of north-south flight lines wherever possible. This negates to a great degree the east-west movement of the sun and the resulting undesirable effect on the imagery. If more flight efficiency is gained flying east-west (such as in Tennessee) or at an angle, the sidelap is increased to at least 40% to offset the sun movement effect.

Acquisition Challenges

Acquisition of NAIP presents many challenges:

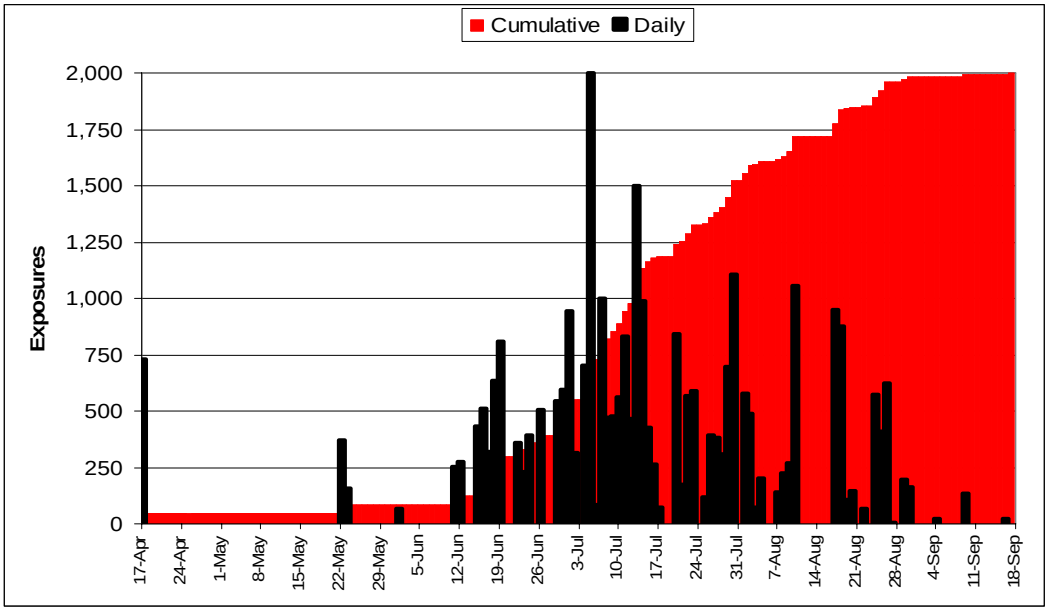
1) Acquiring in front of – and behind – the numerous weather fronts that pass through the country during the summer months. Time and again, our flight data history illustrates periods of storm fronts running 1-2 days and separated by 3-5 days.
2) Dealing with excessive haze and humidity. Thankfully, the superior penetration capability of digital sensors – and appropriate filters – has offset this problem to a great degree.
3) Acquisition very often entails many deployments to pursue clear skies. It is not unusual to fly overnight 2,000 miles or more from one state to another to take advantage of clear skies – and then back again as early as the next day. When we talk about "flocking" we are not imitating feathered wildlife but rather the deployment of multiple aircraft to an area that is suddenly clear and demands attention.
4) In the northwest states in particular, paying attention to the (inevitable) onslaught of forest fires and the resulting smoke (even coming down from Canada). It is not unusual to put a priority collection on an area knowing that the fire season is close at hand.
5) Dealing with Military Operations Areas (MOAs), Restricted Areas (RAs), and Temporary Flight Restrictions (TFRs) require coordination not only with ATC (Air Traffic Control), but also with military controllers. Numerous states have huge expanses of MOAs that require constant communication requiring specific clearance. Additionally, the attendance by the President at a sporting or political event can shut down airspaces/airports for hours. The APFO has been a big help in working through these details with the authorities and the contractors.
6) Dealing with ATC in general. Surdex begins by shipping flight plans to each applicable center and then make follow-up voice contact with each. Since we are flying in Positive Controlled Airspace (PCA, nominally above 18,000' MSL), we are in the realm of commercial airlines – requiring extreme coordination. This generally goes smoothly, but at times can be a bit restrictive. For example, busy centers may dictate one or more of our aircraft leave the area so they don't have to monitor separation distances. Thus, it is not always possible to get multiple aircraft into an area to maximize acquisition.
7) We must deal with multiple state project areas and balancing of priorities against schedule. Since we very frequently ferry aircraft between project areas, over 30% of the hours logged on the aircraft on NAIP consist of ferrying – and not on-the-job acquisition.
8) Dealing with inspection, maintenance, and even repair under FAA guidelines specific to each aircraft. Most turbine aircraft require a basic inspection each 100 hours of flight – with no latitude – and this

may occur 2-3 times during the NAIP effort each year. Thus, aircraft may have to abandon good weather to accommodate the inspection procedure. Some inspections and remedial work can be done within 24 hours, whereas others will put the aircraft in the hangar for up to a week.

Typical Acquisition History

To provide some context, the accompanying graphics summarize the acquisition of imagery done by the Surdex Team in the 2008 NAIP. This consisted of the states of Minnesota, Wisconsin, Tennessee, and Kansas and included ~280,000 square miles of coverage and ~20,000 DOQQs. Only three (3) Conquests were used – more than sufficient capacity, despite extreme rain and flooding in the Midwest in the early summer months. This entailed ~28,000 exposures.

The following chart shows daily (black bars) and cumulative acquisition (red background).



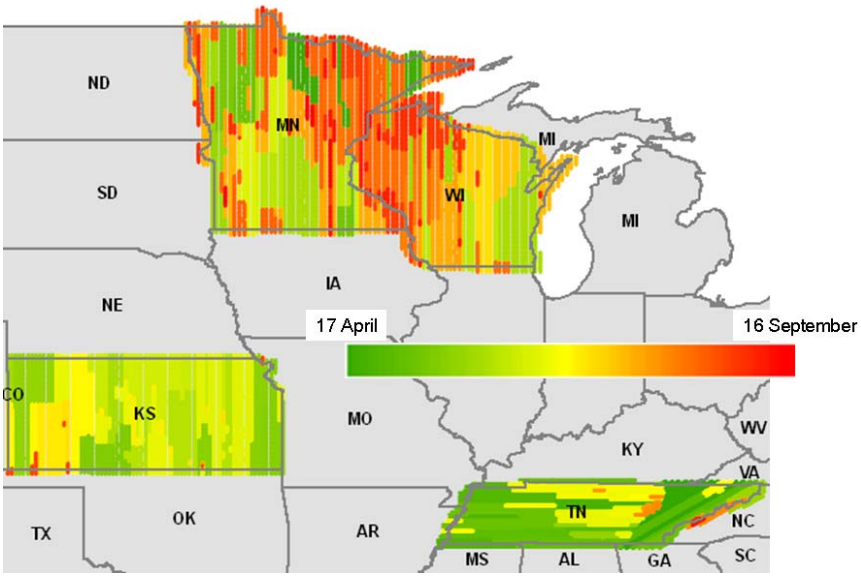
Notice the lack of acquisition from mid-April through mid-June – this was during the intense rain and flooding in the upper Midwest area.

From a summary standpoint:

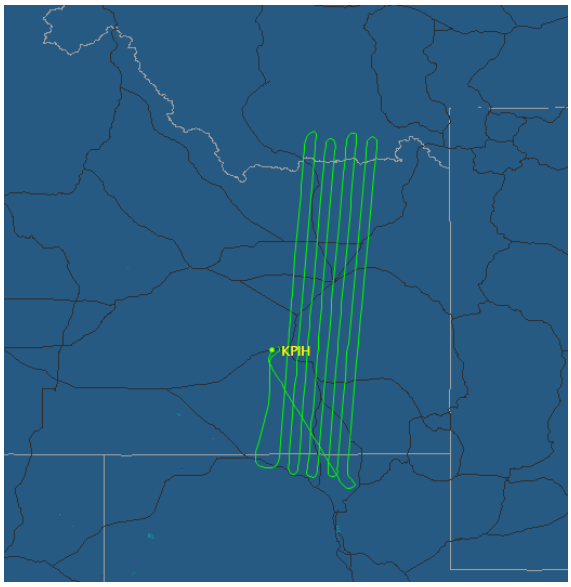
- 154 total days time span – 66 of which acquisition took place (43% of the days).
- ~9 square miles net coverage per exposure, on average (a DOQQ varies from 12-15 square miles, depending upon the latitude of the product).
- Total exposures on a single day (across all project areas and aircraft):
  - Minimum: 8 exposures.
  - Maximum: 2,000 exposures.
  - Average: 468 exposures.

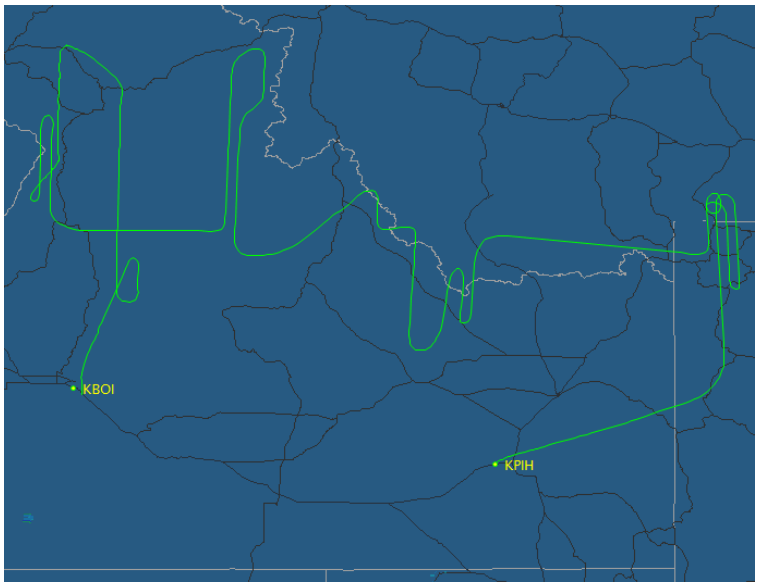
The following graphic illustrates the acquisition sequence, with color coding illustrating the date of acquisition across the 4 states. The sequence somewhat reflects the contractual seasonal windows, but also reflects the chasing of clear weather. This is especially true of MN and WI, where extreme rain and

flooding moved much of the acquisition to later in the windows. In total, only 3 extra days against the planned season windows were required – and these were re-flights.



One of the common phrases around here is a paraphrase of the 80%/20% rule – 80% of the difficulty of completing NAIP acquisition is in the last 20% of the project. Weather and re-flights very often severely chop up an area, leaving the mop-up to only a single aircraft in the latter part of the season window. Our history is that re-flights are an additional ~6-10% of the total acquisition. The graphics below show a cost-and-performance-effective mission (left) and a very expensive mission (right) in which re-flights and small pockets were picked up, both in the Idaho-Utah-Wyoming area from the 2009 NAIP. Both missions took on the order of 5.5 hours, but resulted in over a 20X difference in actual exposures acquired! (*Images from www.FlightAware.com*).





Re-flights can be due to any number of causes, with the bulk of them being self rejects by Surdex that are never even seen by the APFO:

- Clouds/cloud shadow.
- Standing/flooding water.
- Excessive crab, tilt, etc. due to turbulence.
- Snow below the treeline.
- Excessive fire/smoke.
- Sensor equipment failure or malfunction.
- Weak or failed ABGPS/IMU data in a critical area (such as over water or dense trees). Sometimes it is easier to re-fly this than burden production with the issue.

Re-flights require stereoscopic acquisition. That is, no single exposures are re-flown, but rather at least an additional exposure either side. Thus, there will always be "n+2" re-flight exposures around the "n" consecutive exposures that must be re-flown.

Acquisition Aircraft

As the NAIP has grown, top-performing companies such as Surdex increasingly rely upon very high-performance (and very expensive) aircraft. For example, Surdex uses 3 Cessna 441 (Conquest) aircraft, each costing ~$2M and requiring $200-400K in modifications before they can be used – such as cutting holes for camera systems through a pressurized compartment. The Conquest is a pressurized, twin-turbine aircraft capable of flying up to 37,000' at speeds of over 300 knots. Not surprisingly, one of the reasons this aircraft was originally built in the 1980s was to address the corporate travel market. A fully-fueled Conquest can stay aloft for over 7 hours, can re-fuel within 20 minutes, and can ascend to altitude within 30 minutes. This translates to acquisition days exceeding 10 hours spread over one or more "lifts" (missions). With its advanced weather radar, it is not unusual for aircraft from our St. Louis area hangar base to fly 2,000 miles non-stop the night before good weather sets in. In contrast, for safety reasons some aerial photography companies will not ferry twin-piston aircraft at night.

The Conquest aircraft are the "Cadillac" of the NAIP program. We estimate up to 15 Conquests will be used in the 2009 NAIP effort spanning the six contractors involved in 2009. Surdex's experience indicates that one Conquest is the equivalent of 2-3 twin-piston aircraft. This is extremely critical since taking advantage of the limited number of clear days is the key to success. Our rule of thumb is that one Conquest can cover approximately 2 averaged size states each NAIP season (assuming approximately 70,000 square miles per state). As an example, in 2006 Surdex's Team required nearly a dozen twin-piston aircraft to acquire the imagery. In 2009 we have nearly the same total area of coverage and will require only 4 Conquest aircraft.

The inspection rigor for turbine aircraft is the reason why Surdex's aircraft mechanics are fully licensed for FAA inspection, repair, and maintenance – this is now nearly a 100% in-house capability. During intense acquisition, a Conquest may come up for inspection as frequently as every 3-4 weeks. Therefore, despite clear weather observers may notice the aircraft heading to home base. We often synchronize an inspection with a crew change – with the inspection and normal remedial action taking as little as 24 hours. Major inspections are coordinated as much as possible prior to intense periods of acquisition – some accommodate some flexibility in schedule. However, we also occasionally receive ADs (Airworthiness Directives) that mandate immediate ground until inspection and/or remedial action is taken. These often result from accidents in which some part of the aircraft may have been to blame – and all owners/operators must respond. It also seems each year we must deal with a number of repair issues. Though most situations are minor (a day or so each), every once in a while we have major issues such as the replacement of an engine (which can take up to a week).

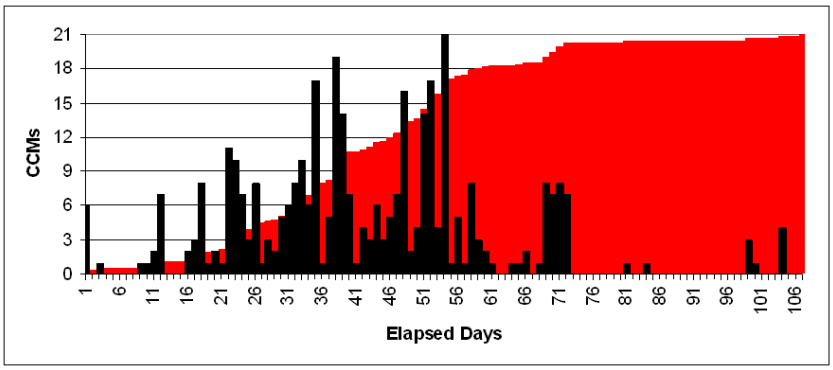
Most acquisition companies have had to (re)invest $500K or more in each Conquest aircraft over the last couple of years. This is partially due to a recent FAA requirement to require RVSM (Reduced Vertical Separation Minimum) equipment in each aircraft – which provides improved collision avoidance and tracking by the centers. Without RVSM, all aircraft (all types) are constrained to less than 28,000' ceiling. In addition, a recent insurance-based directive from the FAA has required an exhaustive and costly inspection of all Conquests, all of which were last manufactured roughly 20 years ago. This is a very intensive inspection taking weeks of time that amounts to nearly completely dismantling the aircraft and putting it back together.

Production of NAIP Products

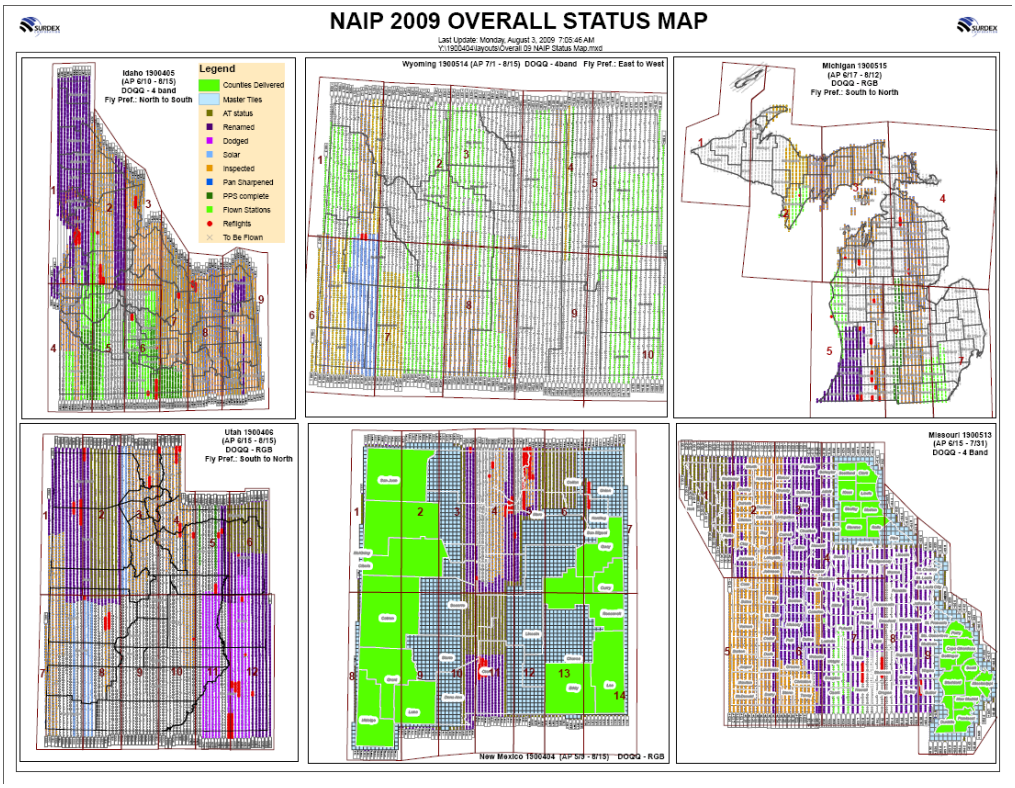
All CCMs and DOQQs are due within 30 days of the closure of a project area season window – not, as some believe, within 30 days of the capture of a county. This is an extremely aggressive schedule never before levied on contractors on a major program. Instead of awaiting acquisition to complete for an entire state project area, production begins as soon as enough imagery is acquired to fill out a number of counties. Production works in large blocks of imagery, generally covering 2,000-5,000 square miles in size. Thus, aircrews are constantly prioritized to ensure that production is as efficient as possible. For example, though clear weather in a new area may be attractive, it is not unusual for an aircraft to be assigned to handle re-flights in small areas that are holding up production.

The following graphic portrays Surdex's experience in the 2008 NAIP. It illustrates the elapsed days between the last acquired exposure that resulted in full county coverage to the day that the CCM is shipped to the APFO. In 2008, all CCMs were delivered within the required timeframe. The black lines illustrate the CCMs on a specific day and the red background shows the cumulative progress. During the course of the project, a "30 day status" is kept to help assess the progress of production.

Within 45 Days: 31%
Within 60 Days: 59%
Within 75 Days: 87%



Production priorities are based on up-to-date status and require daily discussion of priorities and focus. The following graphic illustrates the type of status available to the staff at Surdex. This map portrays the state of acquisition, image processing, all phases of production, and delivery to the USDA. This is an actual graphic from early August, 2009



Given the incremental production of image products, one of the biggest challenges of production is maintaining the highest possible consistency and quality of the imagery across the entire state project area. For most other projects, production takes place after all imagery is in place, simplifying the objective of consistent tone, balance, color, etc. – which we refer to as the "colorimetry". Over the last several years, the APFO has pioneered the use of "imagery metrics" and the use of "reference images".

Relying upon professional imagery experts – and the contractors themselves – the staff at the APFO has taken steps to make image quality assessment more objective and less subjective. Statistical measures for contrast, brightness, color, clipping, etc. are now in place and embodied in a "Best Practices" document. Since inception, this has improved the overall quality of the imagery and inroads have been made toward consistency amongst the contractors.

Soon after acquisition begins, each contractor supplies example reference images for each state project area to the APFO for approval. Once the APFO and the contractor agree on the reference images (some iteration is oftentimes required) the colorimetry for the area is "locked down" and all subsequent imagery is processed to agree with it. Note that this takes place before production of products even begins. This what-you-see-is-what-you-get (WYSIWYG) approach reduces costly and time-consuming rework and improves the ability to achieve schedule.

Surdex has developed much of its own software for the image processing phase. We have developed numerous algorithms, processes, and software that effectively places the burden of colorimetry up front in the process. Since digital acquisition leads to the possibility of "what color would you like?", the reference imagery is the cornerstone of our process. Our process includes the following steps:

1) A *gamma correction* is made to remap the digital imagery to the colorimetry we wish to attain. Image metrics are a key part of this process. Many people do not realize that the response of CCDs is linear, whereas human perception is logarithmic. Without the gamma correction, the compressed midtones would lead to an overall dark appearance of the imagery.

2) A *solar correction* is made to remove the primary effect of sun angle illumination (the "hot spot"), which is very dominant on high-altitude imagery. Our software uses the ABGPS information for each exposure, coupled with solar ephemeris information, to predict the area on each exposure where the sun reflects into the image plane. Technicians then use a variable-sized filter to boost the washed out information in these areas.

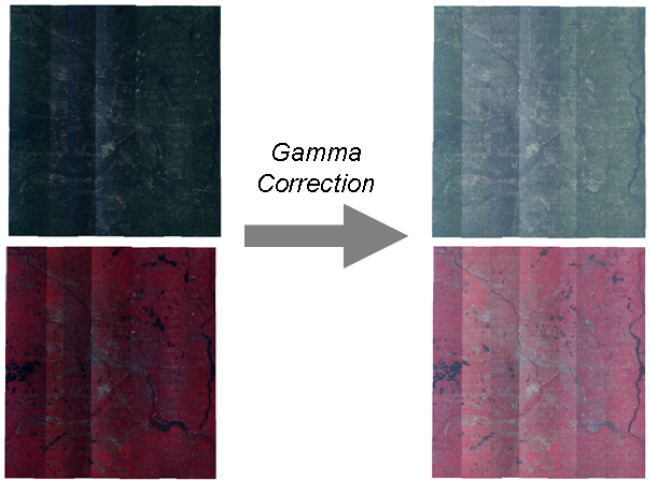
3) *Digital dodging* is performed to remove lingering effects of solar illumination and impacts of atmospheric haze. Thus, localized areas of varying contrast and brightness are resolved.

All of this processing is performed in an environment in which technicians can load thousands of images into the display, courtesy of geocoding supplied by ABPGS/IMU data. Exposures are broken into groups of images with like characteristics, often starting by using those from individual missions. All of the imagery processing steps are performed in an interactive environment, with results prototyped on-the-fly. Once the imagery is consistent over a very large area, the corrections are applied in a series of batch processes relegated to a distributed processing environment. Note that color and color infrared image processing is undertaken at the same time, leading to full 4-band output from this initial phase.

All image processing is performed at full dynamic range (12 bits/pixel or 12 bpp), with the output being either 12bpp or 8bpp (default). Through several years of development, we have proven that the output can be remapped to 8bpp if the final deliverables are also 8bpp (which NAIP is). This is possible because this advanced approach requires very little, if any, further refinement during mosaicking. In other words, "90%" of the colorimetry is established in image processing, prior to all other production steps (aerotriangulation, orthorectification, mosaicking, final packaging, etc.).

The graphics on the following page illustrate the overall image processing approach developed by Surdex. All examples are from the 2008 NAIP effort, in and around the Twin Cities area in Minnesota.

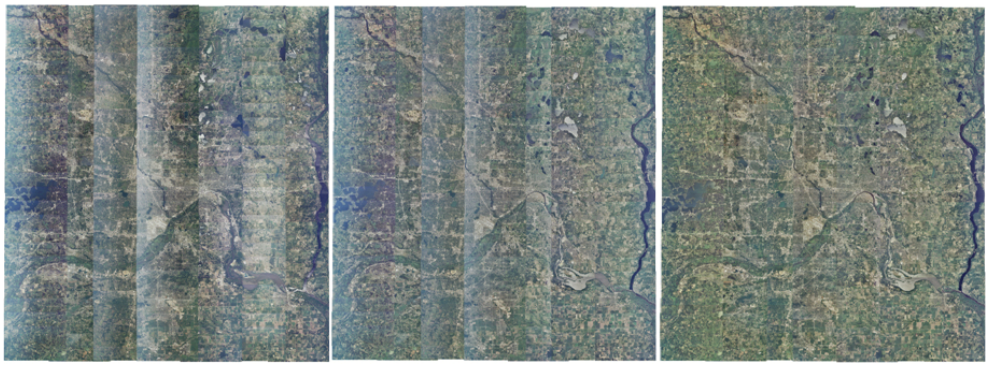
CCDs Have Linear Response – Humans Require Logarithmic Enhancement



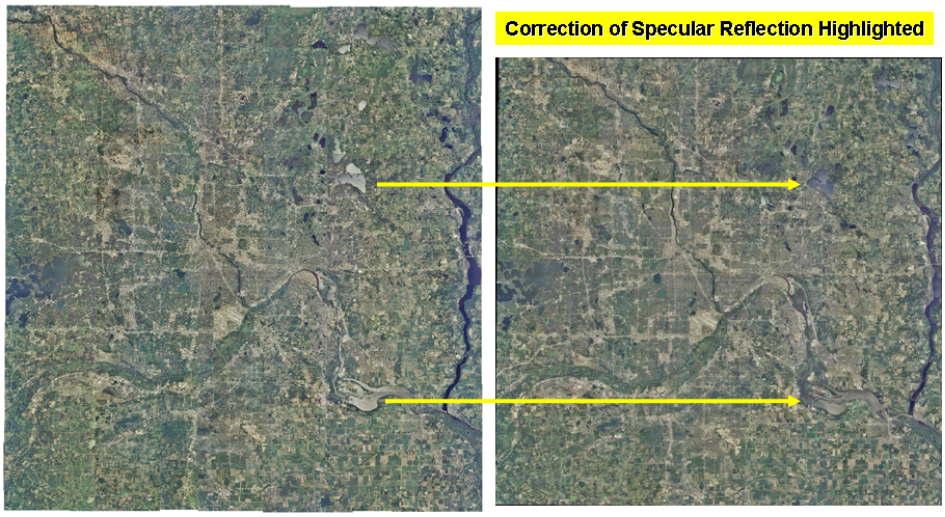
1. Grouping of images
2. Gamma correction
3. Correct to color metrics

Dodging to remove local variations

Solar correction to offset sun illumination



Pre-Production vs Final Product – "WYSIWYG"



A Day in the Life of an Aircrew

Our aircrews have days of hectic activity – and days that staring at rain splattering against the hotel windows is the only option. They operate 364 days a year (we always honor at least Christmas day!), with up to three weeks on the road before time back at home with their families and friends. Unlike airline pilots who can cite their schedules for months to come, our pilots cannot look forward more than a week or so in advance – a reason good pilots are hard to retain in this business. Our crews are comprised of at least two people: the pilot and the sensor operator. In some cases, we deploy another person to work in the hotel preparing and shipping data – even preliminary processing when LiDAR capture is involved – or establishing base stations for ABGPS reduction.

With sun angles starting at around 9am and ending around 5pm, these can be long days involving multiple lifts due to the need to refuel. In addition, the day may end with landing somewhere different than the day began – by design or by necessity. A recent example showed an aircrew based in Albuquerque beginning with acquisition in New Mexico and then moving to Utah and Idaho for more – and then landing in Salt Lake City.

Preparatory activities each morning consist of:

1) Downloading updated flight plans.
2) Laying out a plan for the day, taking into account projected weather. This often includes talking with Surdex's Chief Pilot, who supervises all aircrews of all our teammates also.
3) Prepping the aircraft and camera system for use – including camera port glass to ensure that no oil or grime has accumulated.
4) Sometimes setting up a GPS base station that will operate during the day.
5) Dialoging with ATC before departure.
6) During the day includes acquisition involving up to 3 lifts due to re-fueling, weather, or diversions by ATC.
7) The end of the day is not a quick wind-down:
8) Uploading of flight logs to home base for flight plan updating.
9) Copying imagery to "transfer" drives that will be shipped by FedEx back to home base.
10) Copying ABGPS/IMU data to an ftp site at home base for analysis.

Spending some time performing data management in their hotel room – deleting imagery being kept until home base determining the data was received properly.

Acquisition Coordination

In terms of site basing of our aircraft, planning NAIP acquisition before the season is important but often becomes a moot point once the season begins – Mother Nature is completely in control. For the Surdex Team, our Chief Pilot flies less than one would expect but remains in touch practically 24 hours a day with our own aircrews and those of our subcontractors. The coordination schedule goes something like:

1) Each day aircrews are assigned areas and up-to-date flight plans.
2) After each day of acquisition, aircrews email and/or fax detailed flight logs back to Surdex.
3) Each night, the flight plans are updated with recent progress and with any image rejections noted during image inspection.

4) Flight progress is automatically e-mailed to the APFO each business day to report progress in a standard format. These reports are the basis of the acquisition updates posted by the AFPO to the web site several times a week. Note that with the use of custom flight plans, our database must translate coverage of each exposure to actual DOQQs before issuing the standard report.

Imagery rejections are a given each year and re-flights must be factored in as quickly as possible. Since early acquisition efforts results in large blocks of coverage, one could correctly guess that towards the end of a state's acquisition, the remaining work gets a bit chopped up. As states near completion, acquisition becomes very inefficient due to small, widely-scattered areas. In at least one case in 2008, we noticed an aircraft based in Kansas acquired a few exposures and then proceeded on to more mop-up work in both Minnesota and Wisconsin – and not landing once. Too bad the aircrews don't get frequent flyer miles!

As for deployment and decisions made as to where the individual aircraft should be, this is truly a black art placed in the hands of an experienced expert and subject to criticism and second-guessing by everyone involved in the project. In other words, our Chief Pilot must have a leather skin covered with Kevlar. The decisions are based on the basic parameters of:

1) Window schedules in each state.
2) Amount of acquisition required in each state.
3) Climate and weather histories in each state – and in the case of the northwest, fire/smoke projections.
4) Short and long-term weather projections – flock to the projected clear skies.
5) Progress to date – generally speaking, states running behind schedule will get priority.
6) Prioritization of re-flights.

What this amounts to is the simple and inevitable fact that not every clear day in each state will result in acquisition on that day. It is intractable (and too cost-ineffective) to base aircraft in states and leave them there for the duration. However, the oft-used adage is "more bad days turn good than vice versa" has been proven to be quite accurate.

We have used small regional subcontractors in the past using film cameras – nearly always with lower-performance aircraft – with some limited success. However, with the increasing requirement for digital sensor acquisition, few small companies have such instrumentation and the highly efficient aircraft needed to ensure performance.

Capacity Assessment

Unlike smaller projects (even including statewide projects), the complexity and rigor of NAIP defy standard logic and estimating models. Without the benefit of years of participation in the NAIP, Surdex would be ill-equipped to assess capacity and estimate cost. Since acquisition is generally 70+% of the cost of NAIP, errors in these estimates are not looked upon kindly by our shareholders. Likewise, errors in capacity are not viewed favorably by the government!

The difficulty in estimating our acquisition resources, capacity, and cost is based on estimating the amount of ferry time (sometimes referred to as cross-country or mobilization time). This is the amount of time allocated to moving aircraft to and from the various areas to chase clear weather. At times in the past NAIP efforts, we have spent nearly as much time ferrying aircraft as we have acquiring the imagery. This is where highly efficient aircraft, experienced crews, and experienced coordinators come into play. The more effective each is, the better our performance and the less we have to move aircrews around. It also should come as no shock that weather plays a substantial part – in some years bad weather has increased our cost and in the good years helped contain costs.

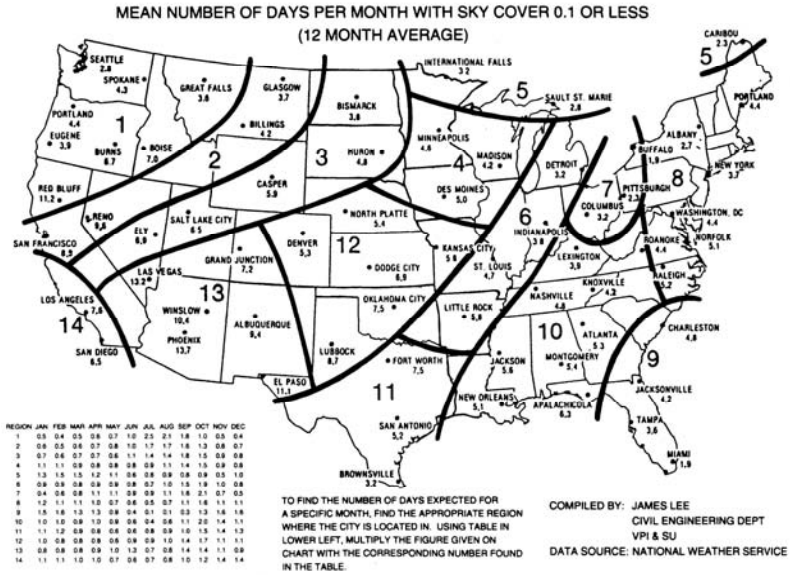
Capacity assessment begins with an analysis of resources required for each prospective state – mainly amounting to assessing a level of difficulty. As the government and the contractors have learned over the years, geographic grouping of states helps – along with a dose of separating the groups. For example, in 2009 Surdex has the 4 mountain states of NM, UT, ID, and WY along with the Midwestern states of MO and MI. The two groups (mountain and Midwestern) allow us to essentially dedicate one or more aircraft to each group – roaming the states in the group around local weather patterns. In turn, the separation of the groups sometimes afford us the ability to move all aircraft to a group as a largely regional weather issue sets in.

In preparation for our proposal to the government, we perform an analysis to determine which states – and how many states – our team can take on. Part of this is a function of our Team's capacity, part of it is based on the specifics of each state project area, part based on the available hours each day as a function of sun angle, and part based on projections of clear days. Surdex has developed software that ingests the requirements for each state and performs an analysis.

The information used for each state project area includes:

- The number of seasonal windows, varying from a single to up to 4 windows.
- The start date and end date of each window.
- The number of DOQQs in each window.

The clear weather chart (shown below) was developed in the 1980s and represents the "Mean Number of Days per Month with Sky Cover of 0.1 or Less." Most acquisition companies consult this chart on a regular basis – tempered with a dose of experience. The chart breaks the country down into regions having similar characteristics. A table pairs each region against each month of the year, showing the expected number of days each month with reasonably clear skies ("0.1 or less"). Combined with the computed number of hours each day encompassing at least 30° of sun angle, Surdex has developed a digital form of the chart and the table and software that analyzes the specifics of each window, resulting in an overall analysis.



REGION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.5	0.4	0.5	0.6	0.7	1.0	2.5	2.1	1.8	1.0	0.5	0.4
2	0.6	0.5	0.6	0.7	0.8	1.0	1.7	1.7	1.8	1.3	0.8	0.7
3	0.7	0.6	0.7	0.7	0.6	1.1	1.4	1.4	1.8	1.5	0.8	0.8
4	1.1	1.1	0.9	0.8	0.8	0.8	0.9	1.1	1.4	1.5	0.9	0.8
5	1.3	1.5	1.5	1.2	1.1	0.6	0.8	0.9	0.8	0.9	0.5	1.0
6	0.9	0.9	0.8	0.8	0.9	0.8	0.7	1.0	1.5	1.9	1.0	0.8
7	0.4	0.6	0.8	1.1	1.1	0.9	0.9	1.1	1.6	2.1	0.7	0.5
8	1.2	1.1	1.1	1.0	0.7	0.6	0.5	0.7	1.1	1.6	1.1	1.1
9	1.5	1.6	1.3	1.3	0.9	0.4	0.1	0.1	0.3	1.3	1.6	1.8
10	1.0	1.0	0.9	1.0	0.9	0.6	0.4	0.6	1.1	2.0	1.4	1.1
11	1.1	1.2	0.8	0.8	0.6	0.6	0.8	0.9	1.0	1.5	1.4	1.3
12	1.0	0.8	0.8	0.8	0.6	0.9	0.9	1.0	1.4	1.7	1.1	1.1
13	0.8	0.8	0.8	0.9	1.0	1.3	0.7	0.8	1.4	1.4	1.1	0.9
14	1.1	1.1	1.0	1.0	0.7	0.6	0.7	0.8	1.0	1.2	1.4	1.4

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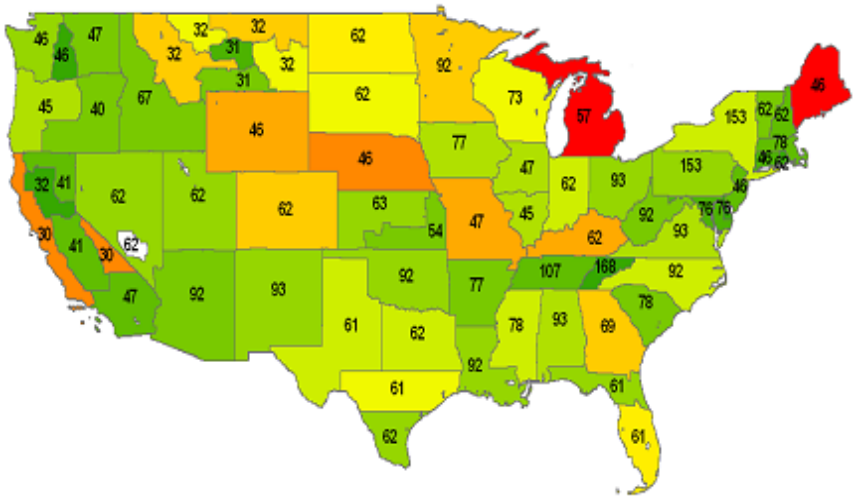
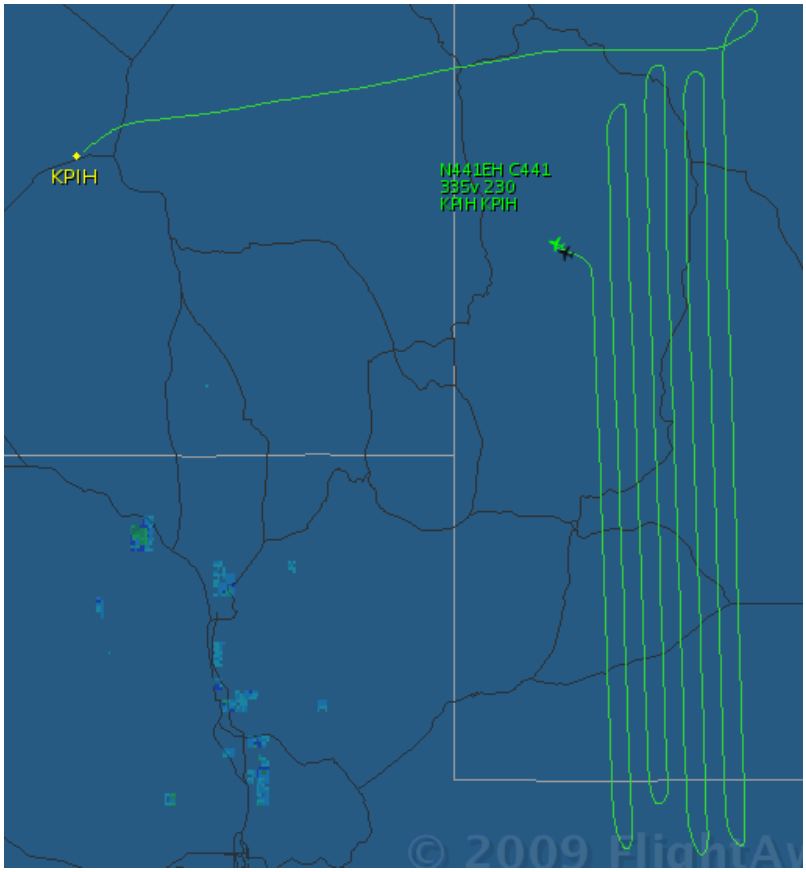
Our analysis for 2009 of each state seasonal window in the entire NAIP effort is portrayed in the following graphic. Green portrays easier windows, yellow/orange more average windows, and red representing the more difficult windows. This analysis is not perfect by any means, but does present a good overall view. For example, we know the Gulf Coast States are more problematic than shown in the analysis. These states have reasonably clear days that are broken up by periods of popcorn clouds reacting to humidity and moisture – not to mention the occasional hurricane. The numerical values in each window notes the number of acquisition days in the window.



Some of the results can be perplexing at first glance. However, one must take into account the length of each window and the quantity of the DOQQs. For example, a long window with a small number of DOQQs may result in an optimistic assessment (such as TN, known to be a bit of a bear to acquire), but the length of the window is the key – many days are available. Michigan (as many of us golfers know) is blessed with lots of long days in the summer, looks pessimistic. In reality, however, its rating is biased by adverse weather in the upper peninsula, which is plagued by the "lake effect".

Monitoring Flights

Though we have sophisticated tools for tracking and monitoring our aircraft operations, a number of us use free software from FlightAware (www.flightaware.com). You can enter aircraft tail numbers and watch what is happening in real time. The following graphic shows a recent flight over Wyoming. The aircraft tail number on the display is followed by the aircraft type (C441 is a Cessna 441 Conquest). The numbers below are its altitude in 100's of feet (in this case 33,500 and descending ("v")) and airspeed (230 knots). The last line lists originating and destination airports (Pocatello, Idaho in this case).



Closing

This white paper was prepared by Craig Molander, Senior Vice President of Business Development for Surdex Corporation. If there are any questions or comments regarding this paper, please feel free to contact him at any of the following:

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