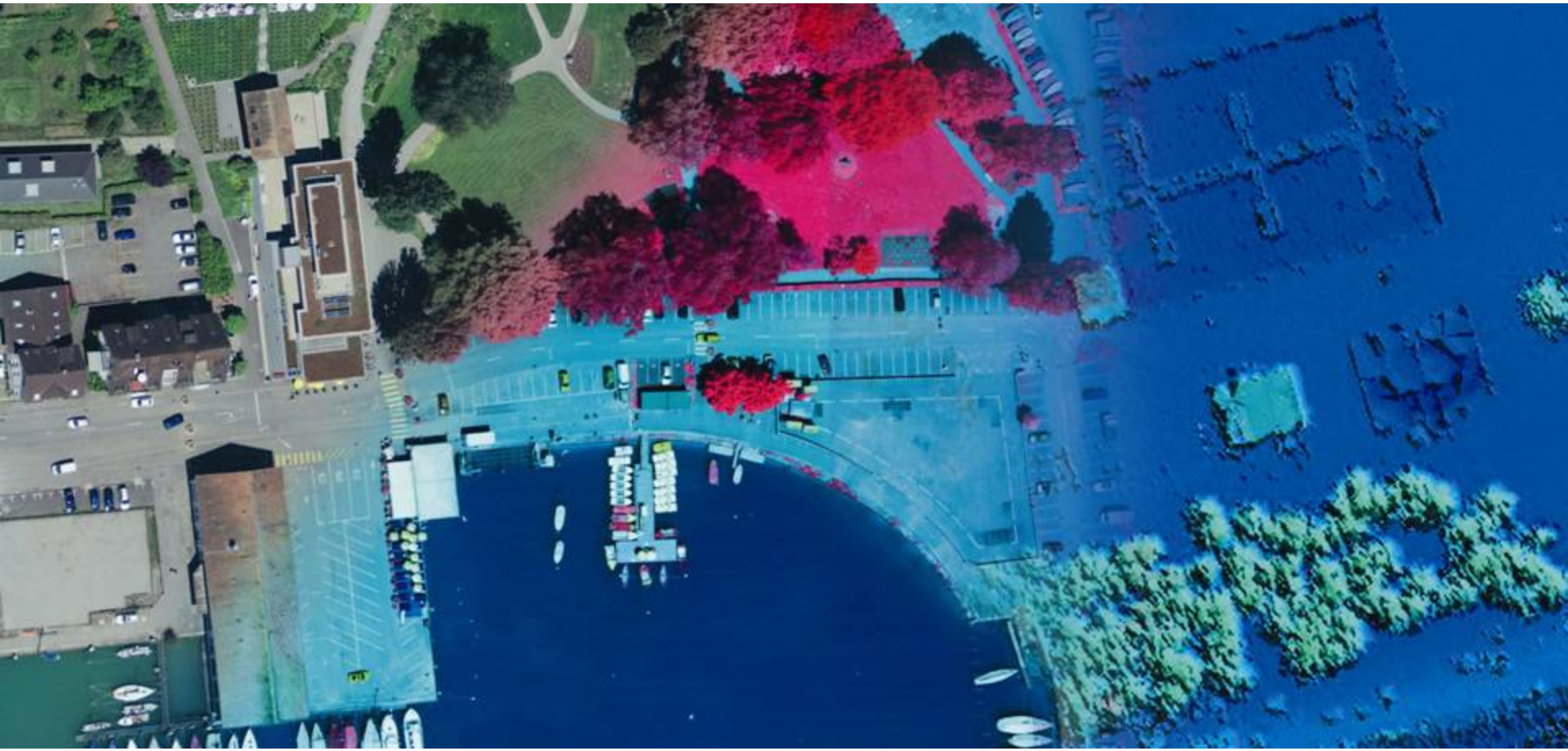
Leica Geosystems
National Digital Orthophoto Program Meeting
October 8, 2008



Latest Advances in Aerial Digital Sensors

Shawn Slade – Airborne Imaging and LiDAR Sales

- when it has to be **right**

Leica Geosystems

A heritage of trust,
a history of getting it right

188 years of Measurement Technology

2005 Acquisition by **Hexagon AB**

2004 Divestment **Swiss Optics** and **Escatec**

Acquisition **Tritronics**

2002 Divestment **Vectronix (defense)**

2001 Acquisition **Cyra,** Acquisition **Laser Alignment**

Acquisition **ERDAS,** Acquisition **LH Systems**

2000 IPO at Swiss Exchange (SWX)

1997 Leica Geosystems

1994 Acquisition **GPS-Magnavox (US)**

1990 Merger of Wild-Leitz and Cambridge Instr into **Leica**

1988 Acquisition **Kern, Aarau**

1986 Merger of Wild and Leitz into Wild-Leitz

1921 **Wild** founded in Heerbrugg, Switzerland

1819 **Kern** founded in Aarau, Switzerland

Decades of innovation
dedicated to quality

2006	World's first "two pulse in air" **LIDAR**
2005	World's first total measurement station with integrated GPS, the Leica Geosystems **SmartStation**
2004	First **universal GPS/TPS surveying system** and world's first mobile coordinate measurement technology system – the **T-Probe** and **T-Scan**
1993	World's first handheld **laser distance meter**
1991	First industrial **laser tracker**
1984	First **GPS for surveying**
1969	First **infrared-based distancer**
1925	First **aerial photography camera**
1921	World's first **portable opto-mechanical theodolite**

In total, Leica Geosystems holds more than 1,000 patents, many of them registered in the past decade

Leica Geosystems – Rhine Valley headquarters

Headquarters in Heerbrugg since 1921 (former Wild Heerbrugg)

Switzerland

- Heerbrugg

Airborne Products from Leica Geosystems

ADS80 – Aerial Digital Sensor

ALS60 and ALS-Corridor Mapper Airborne Lidar

RCD105 Digital Frame Camera

RC30 – Film Camera

IPAS20 – Inertial Positioning & Attitude system

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ALS technology
changing the paradigm…still

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Mt Hood Oregon

WatershedSciences

6 points per meter squared post processed to a 1-meter DEM product

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History, where the ALS60 has evolved from…
ALS40 components

large aperture scanner for high-altitude work

Scanner assembly

- 23.5 x 35.8 x 21.8 inches, 120 lb
- 60 x 91 x 55 cm, 55 kg

Equipment rack

- 19.0 x 20.6 x 25.0 inches, 140 lb
- 48 x 52 x 64 cm, 64 kg

Laptop control computer

Post-processing software

Manufactured 1997 - 2005

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ALS50-I+ components
compact system for installation many aircraft types

Scanner assembly

- 22.0 x 13.4 x 9.5 inches, 65 lb
- 56 x 37 x 24 cm, 30 kg

Equipment rack

- 19.0 x 20.6 x 25.0 inches, 140 lb
- 48 x 52 x 64 cm, 64 kg

Laptop control computer with GUI

Post-processing software

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ALS50-II components
further refinements with expanded altitude range

Scanner assembly

- 22.0 x 13.4 x 9.5 inches, 65 lb
  (less 55 lbs from ALS40)
- 56 x 37 x 24 cm, 30 kg

Rackless electronics

- 17.5 x 18.5 x 14.0 inches, 88 lb
  (less 52 lbs from ALS50-1+)
- 45 x 47 x 36 cm, 40 kg

Airborne-qualified operator interface with GUI

Post-processing software

Highly integrated flight management

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ALS60 and MPiA
performance without compromise

More than ever, one system for all applications

No longer do customers have to choose between high pulse rate and high accuracy

No longer do customers have to choose between small size and high altitude capability

A new paradigm: the point density you want, the accuracy you need

Significant improvements in ALS60
making a great LIDAR even better

Compact scanner now accommodates even the highest-performance IMUs

Reduced cabling for easier transport and installation

Dual handles and top-mounted tie-down hardware for easier installation

High-speed scan mirror design for tighter along-track spacing

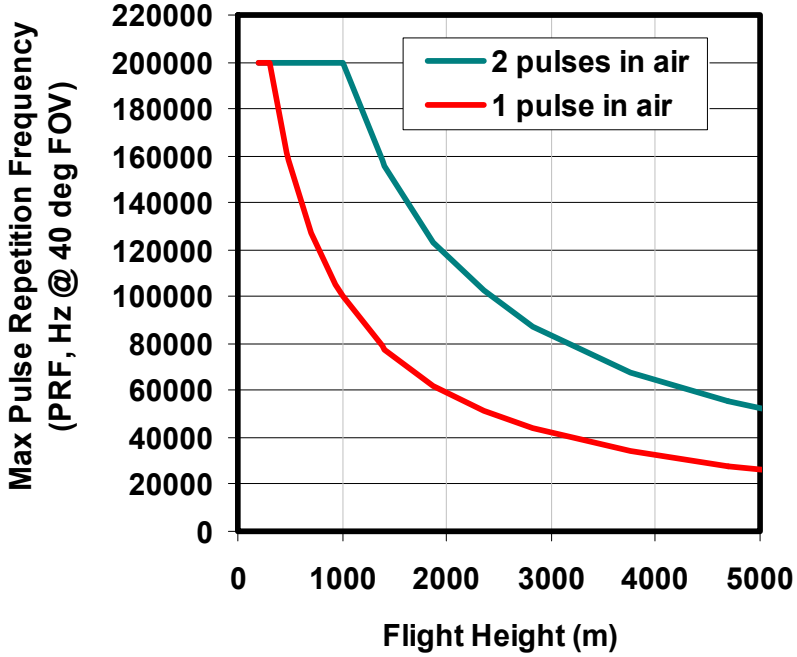
6000 m AGL mirror option available for ultra-high-altitude use

Significant improvements in ALS60
making a great LIDAR even better

33% increase in maximum pulse rate

200 kHz at the ground for even higher point density

Smooth operating envelope without discontinuities



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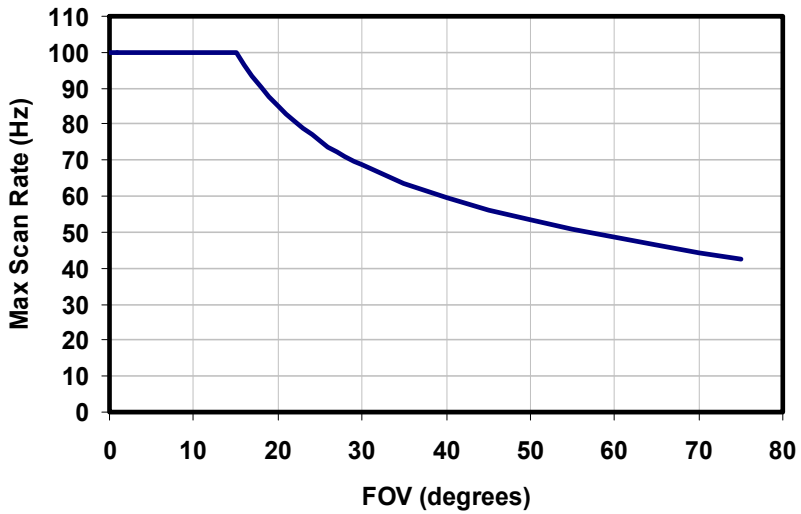
Significant improvements in ALS60
making a great LIDAR even better

10% increase in maximum scan rate to 100 Hz

20% increase at most FOVs for optimal point pattern at all FOVs



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Large optical aperture
the heart of a flexible system

Detect smaller targets at higher altitude (e.g., power line profiling)

Fewer “drop outs” on low-reflectivity terrain features (e.g., asphalt pavement)

Highest available maximum altitude

- Widest coverage on large area/low point density projects
- Fly at constant altitude, even over mountainous terrain

Fly in less-desirable atmospheric conditions (e.g., haze/smoke)

Preserves performance, *even at today’s high pulse rates*

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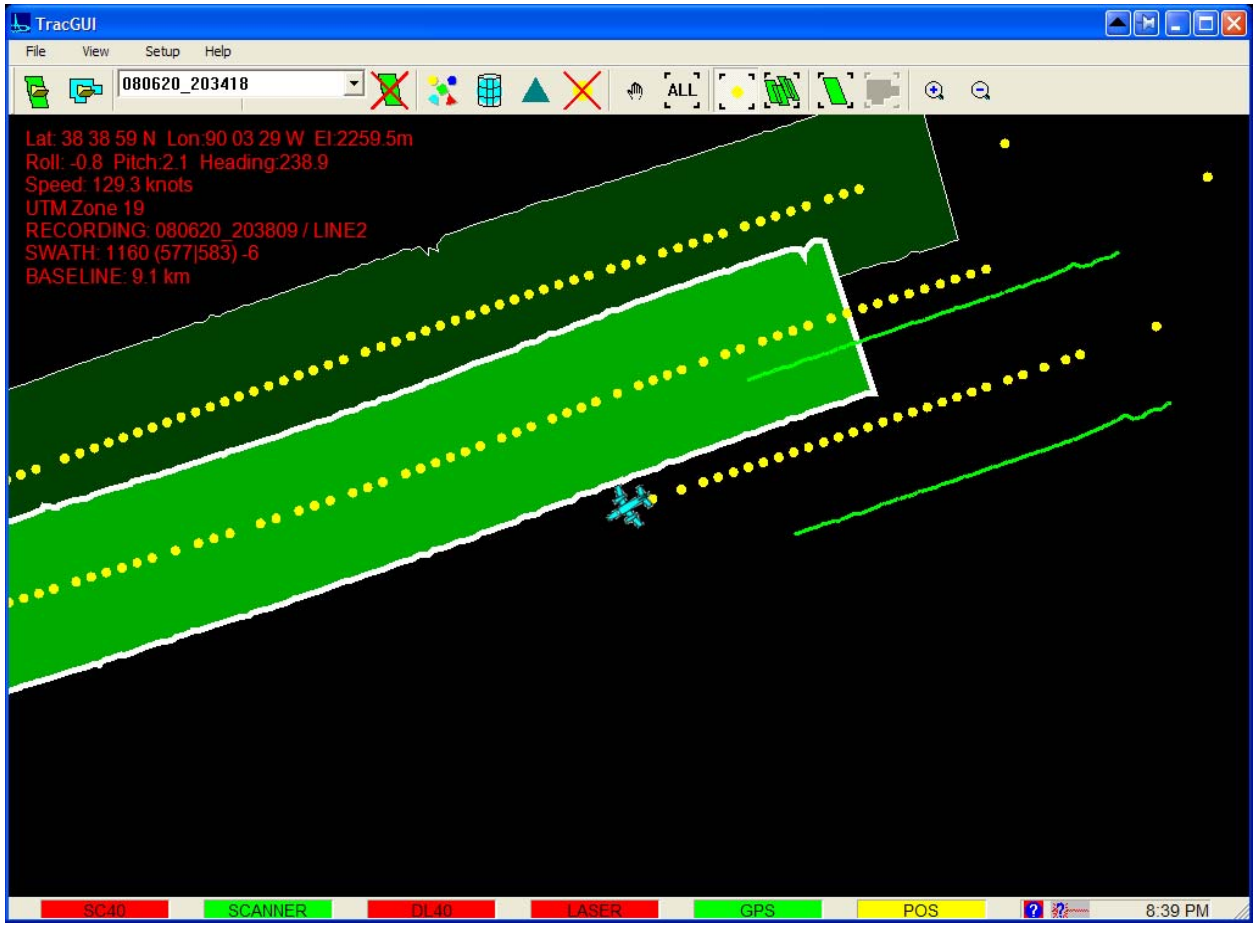
Real time coverage verification
ensures total site capture before leaving area



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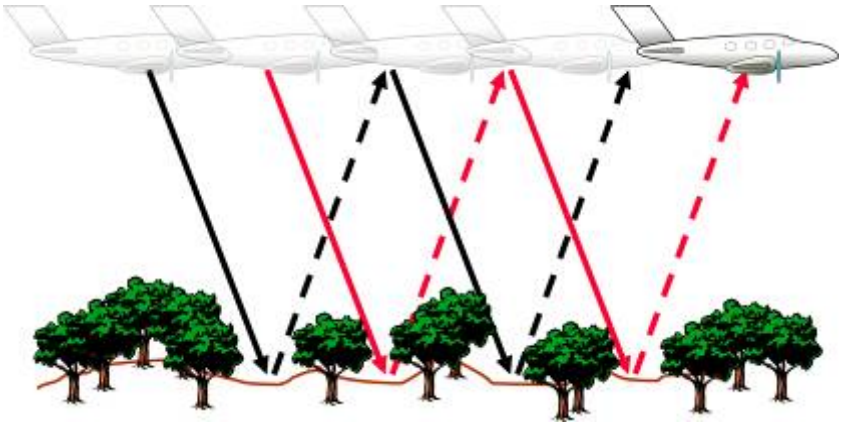
MPiA that really works
at the altitudes you need it most

Significant benefits

- Double the data density at current swath
- Double the swath at current density
- Data acquisition cost savings approaching 50%

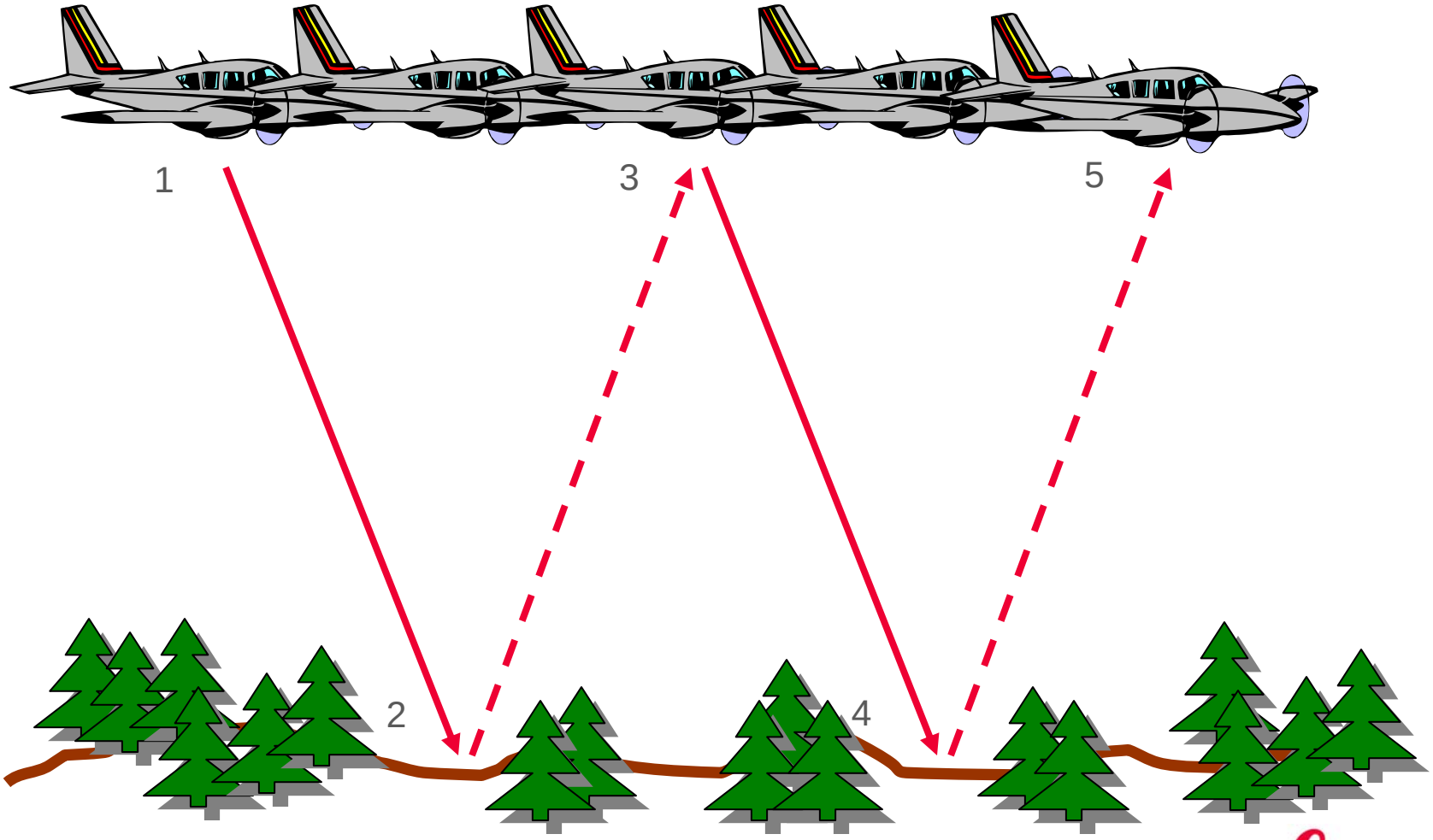
Leica MPiA technology

- Proven in dozens of Leica Airborne Laser Scanners
- Works all the way to maximum rated altitude



Fundamentals of MPiA technology

single-pulse technology limits pulse rate



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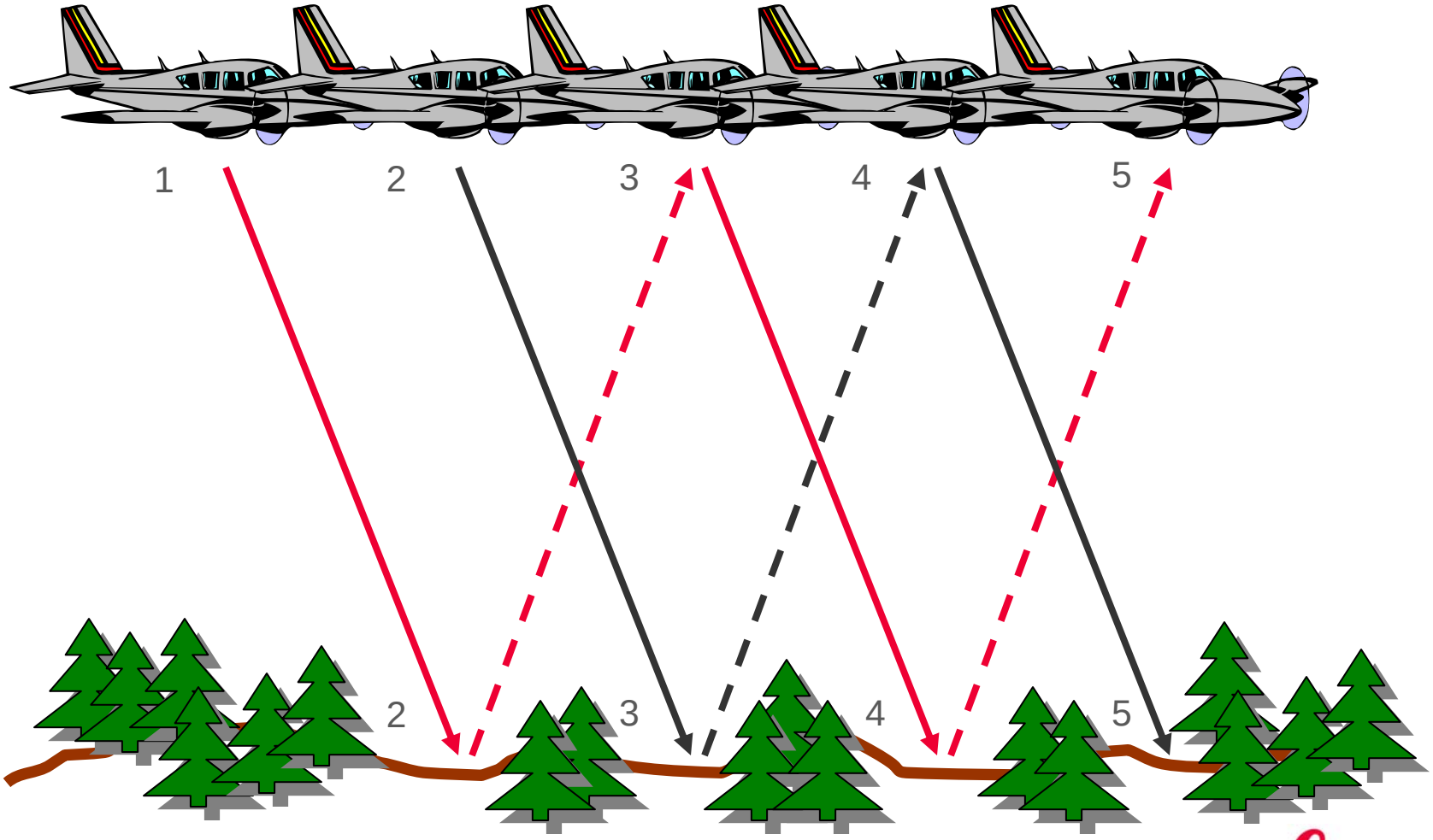
Fundamentals of MPiA technology

MPiA allows doubling of pulse rate



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Significant improvements in ALS60
making a great LIDAR even better

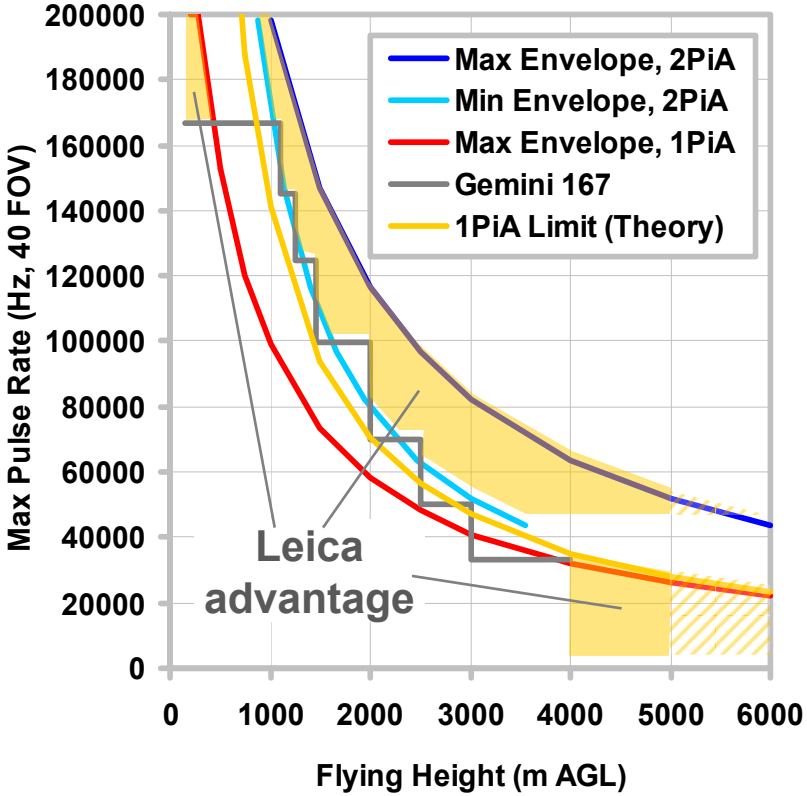
200 kHz at-the-ground pulse rate for higher point density

33% increase in maximum pulse rate over ALS50-II

Smooth operating envelope without discontinuities

ALS60 200 kHz pulse rate attainable at up to 280 m AGL for 1PiA and 990 m AGL for 2PiA (@ 40 FOV)

6000 m AGL still attainable using ALS50-II scan mirror ( )



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MPiA Project overview
largest privately-undertaken LIDAR project

Total area : 750,000 km²

- **5% from archive**
- **95% new acquisition**

Flying season

- **May to October for prairie areas**
- **July and August only in mountainous areas**

Project specs

- **1.0 – 1.5 m post spacing**
- **20 cm Z accuracy, 50 cm XY accuracy**

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An interesting effect
getting more than a 2:1 benefit from MPiA

Baseline: achieving 1.0 m post spacing

With no terrain relief MPiA did not offer quite 2:1 advantage

Any terrain relief results in lowered net swath

Flying higher with MPiA yields less swath loss due to terrain relief

As amount of terrain relief increases, the difference in net swath width resulting from MPiA use increases dramatically

	Terrain relief (m)					
	None		300		600	
Configuration	MPiA	1PiA	MPiA	1PiA	MPiA	1PiA
Pulse rate (kHz)	120	89.3	120	89.3	120	89.3
Flight height (m above terrain)	1600	1100	1300-1600	800-1100	1000-1600	500-1100
Side overlap required (%)	20%	27	38	53	56	79
Net sawth width (m)	927	583	721	376	514	170
MPiA advantage	1.59:1		1.92:1		3.02:1	

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Results
2007 season

260 missions flown

3.28×10^{11} points acquired, 2.64×10^{11} archived

Point spacing objectives were met

Accuracy objectives were met

- <20 cm Z accuracy in mountainous areas
- In prairie areas, boresight calibration was refined until line-to-line match was in the area of 3-4 cm Z

Use of MPiA resulted in ~2:1 advantage in acquisition time versus SPiA

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Conclusions

MPiA technology truly validated

MPiA technology is ideal for improving acquisition rate of large point clouds

MPiA use does not sacrifice data quality

More comfortable flying height allows point density to be achieved at less turbulent altitude, reducing flight crew fatigue

MPiA can actually exceed the 2:1 benefit predicted on a single-flight-line basis

Use the highest performance IMU available

Employing multiple aircraft has benefits in efficiency by reducing GNSS base station deployments

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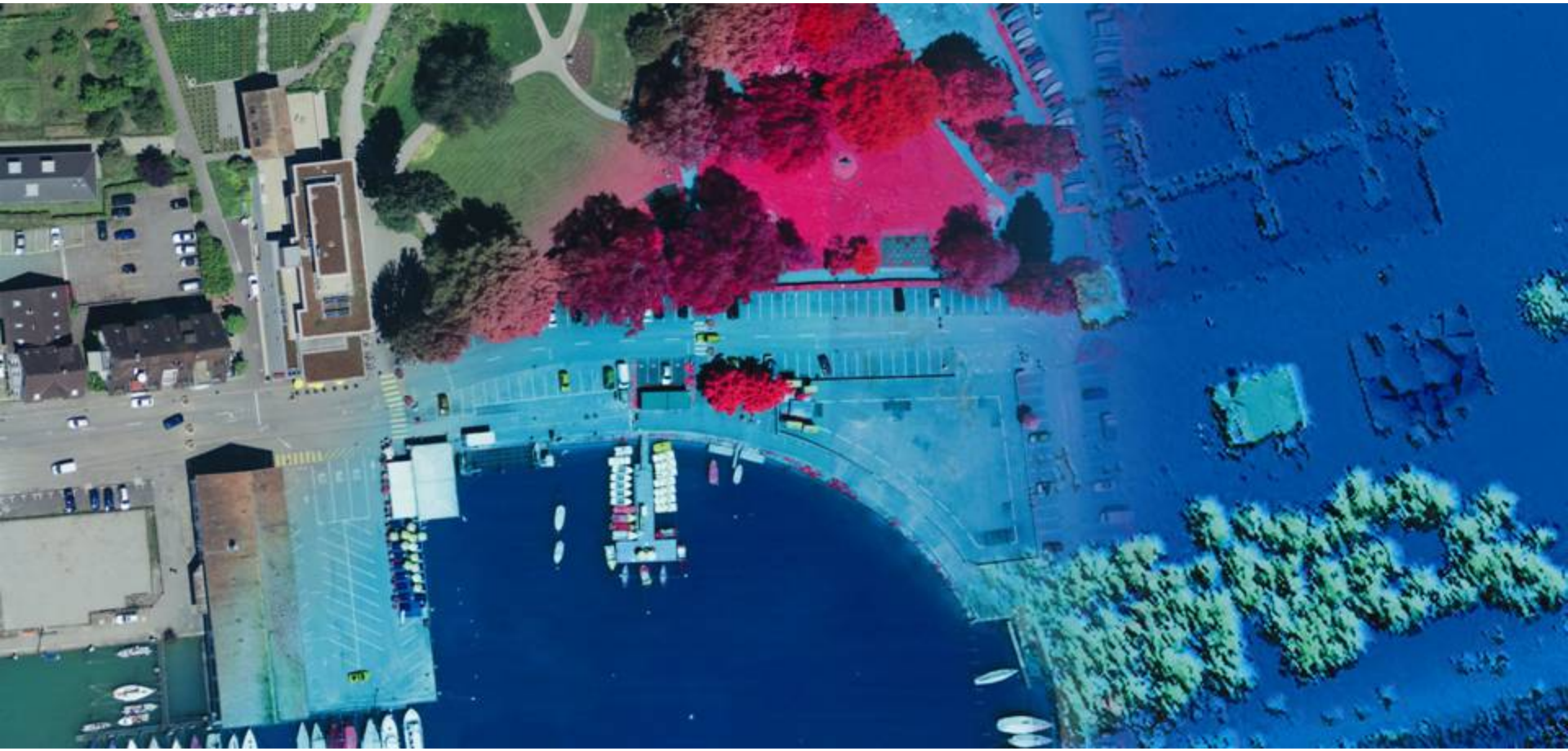
ALS Corridor Mapper



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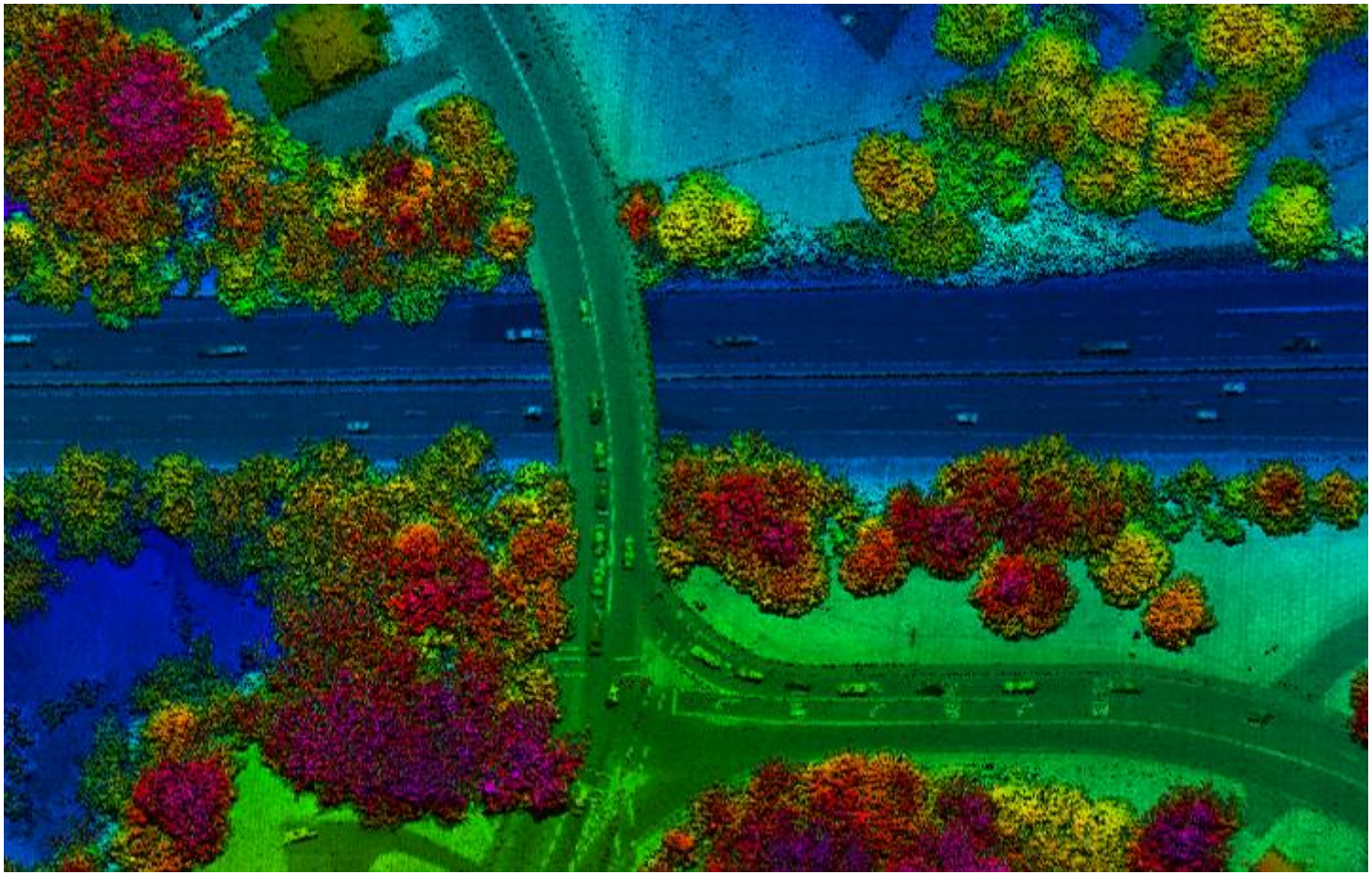
ALS Corridor Mapper

ALS60 performance for corridor applications



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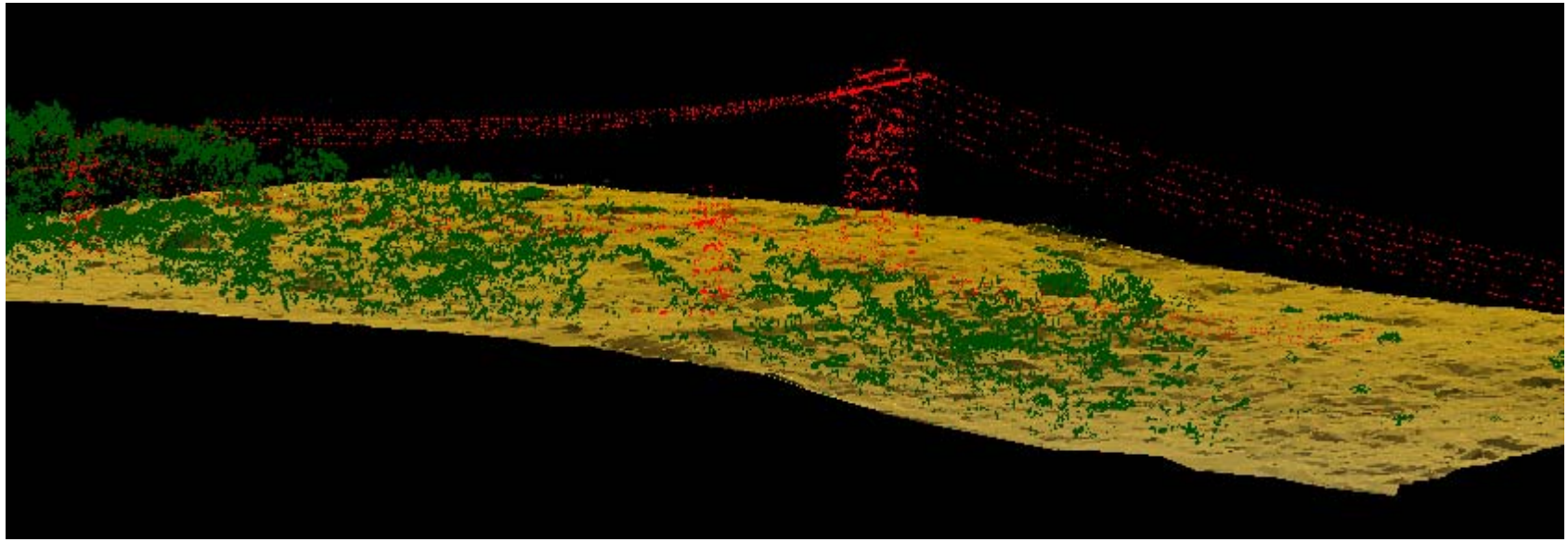
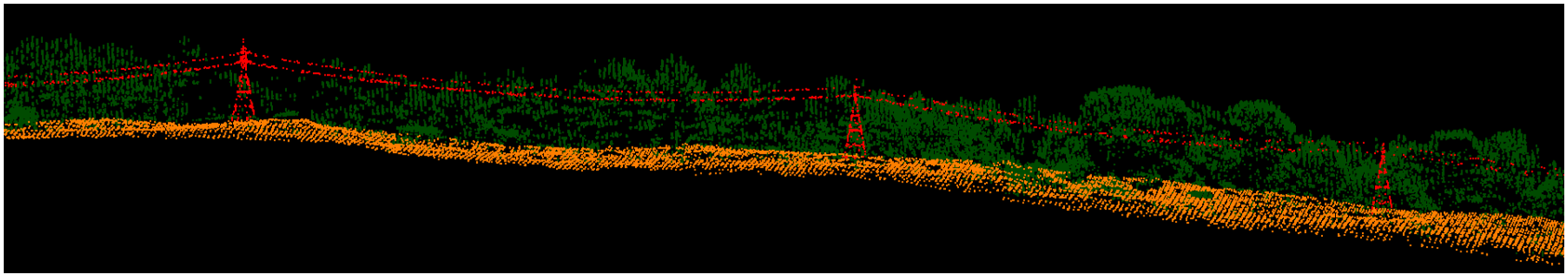
ALS Corridor Mapper

ALS60 performance for corridor applications





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RCD105 Digital Frame Camera for ALS LIDAR

High performance imaging for LIDAR

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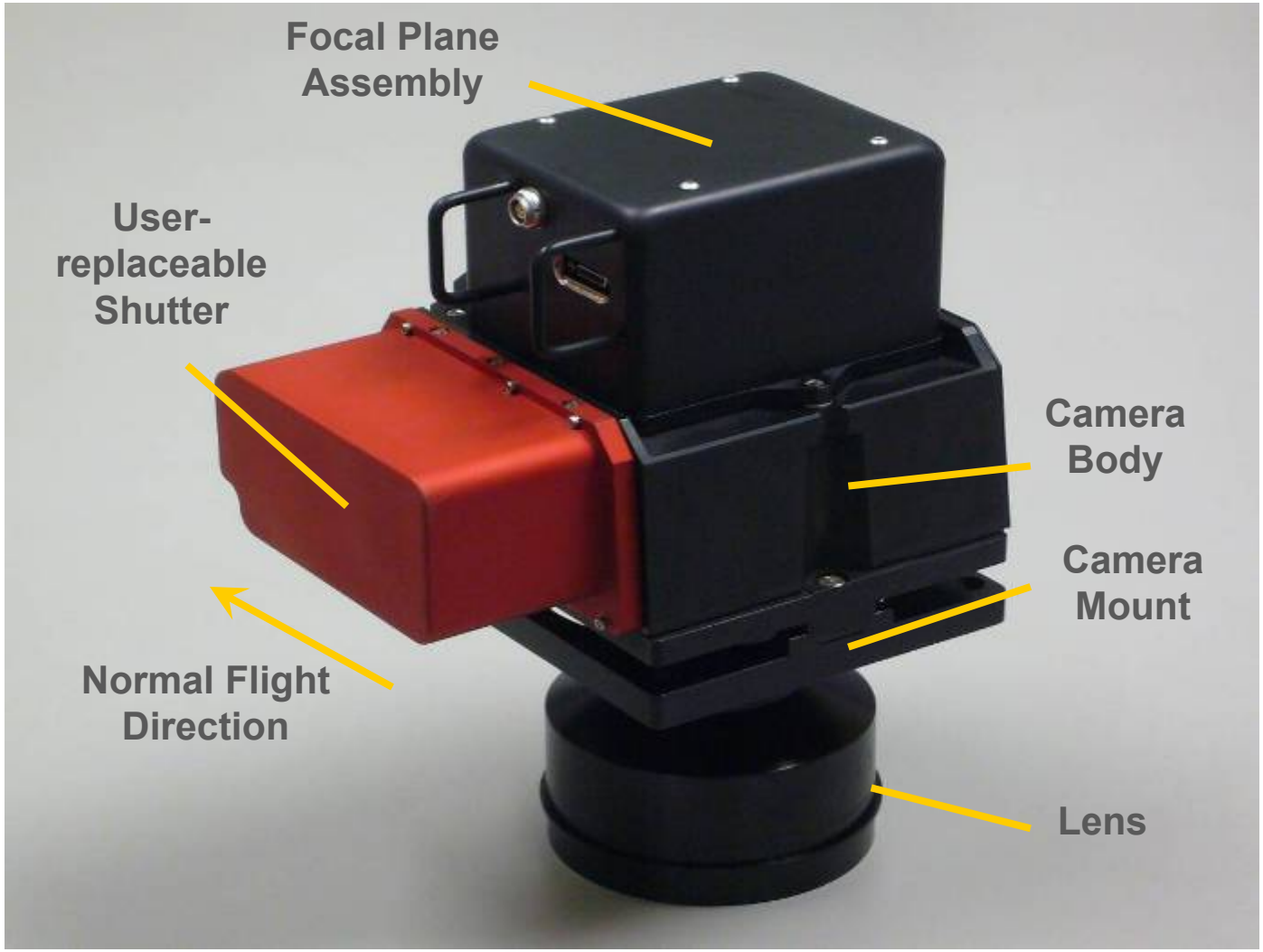
RCD105 39MP Camera Head

Major Components



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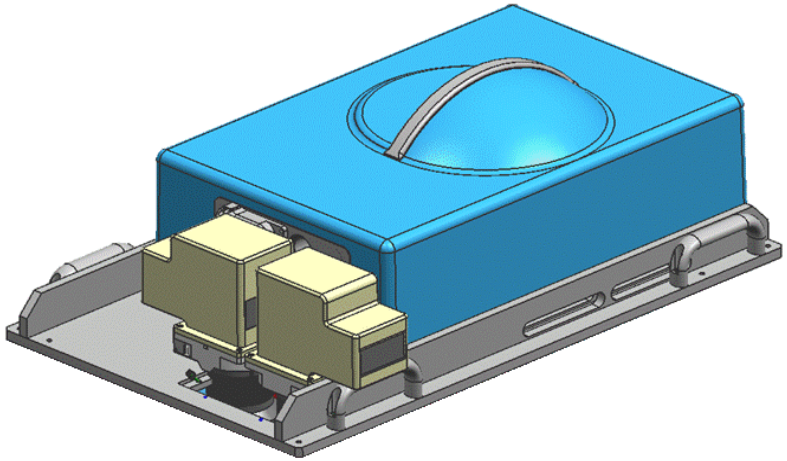
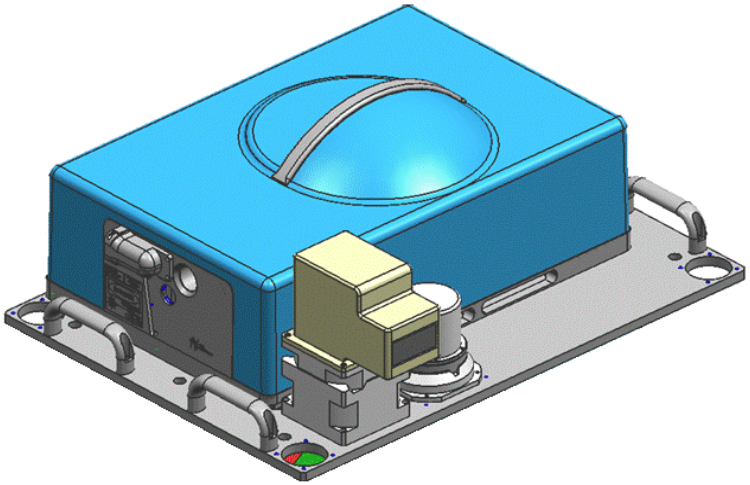
RCD105 Camera Head
typical installations



Front-mount, dual RCD105s, non-isolated



Side-mount, RCD105 + thermal sensor, isolated

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RCD105 Digital Frame Camera
39 MP: fast, flexible, plug-and-play with ALS LIDAR

Purpose-designed airborne camera

RGB or CIR operation

35, 60 and 100 mm lenses

Fast 2.2 second frame interval

User-replaceable 1/3600-sec shutter

Up to 2 camera heads per controller

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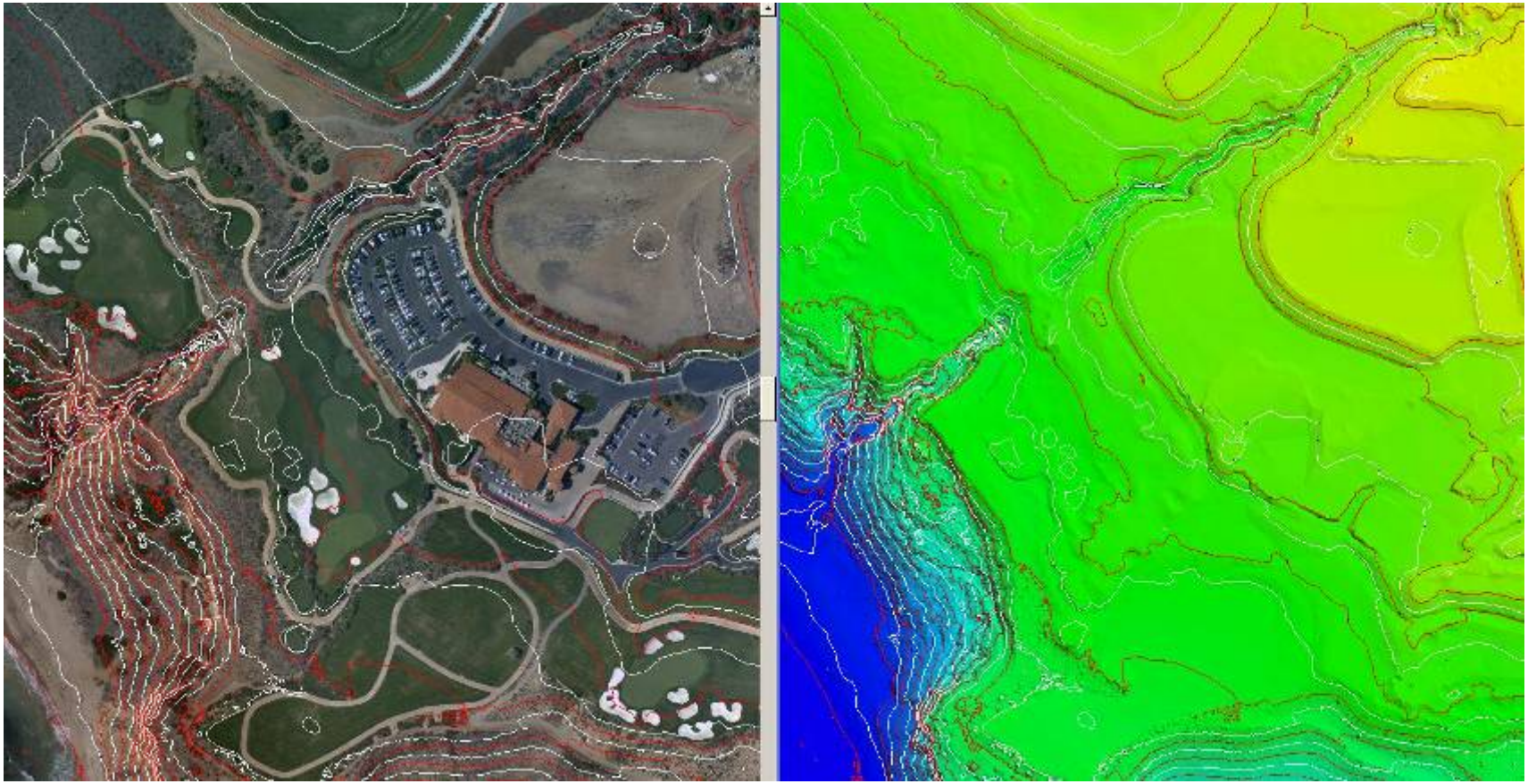
Medium format imagery with ALS LIDAR
an ideal combination



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Film vs. Digital Images

RCD105 – 17 July 11:30am

RC30 – 21 July 11:30am

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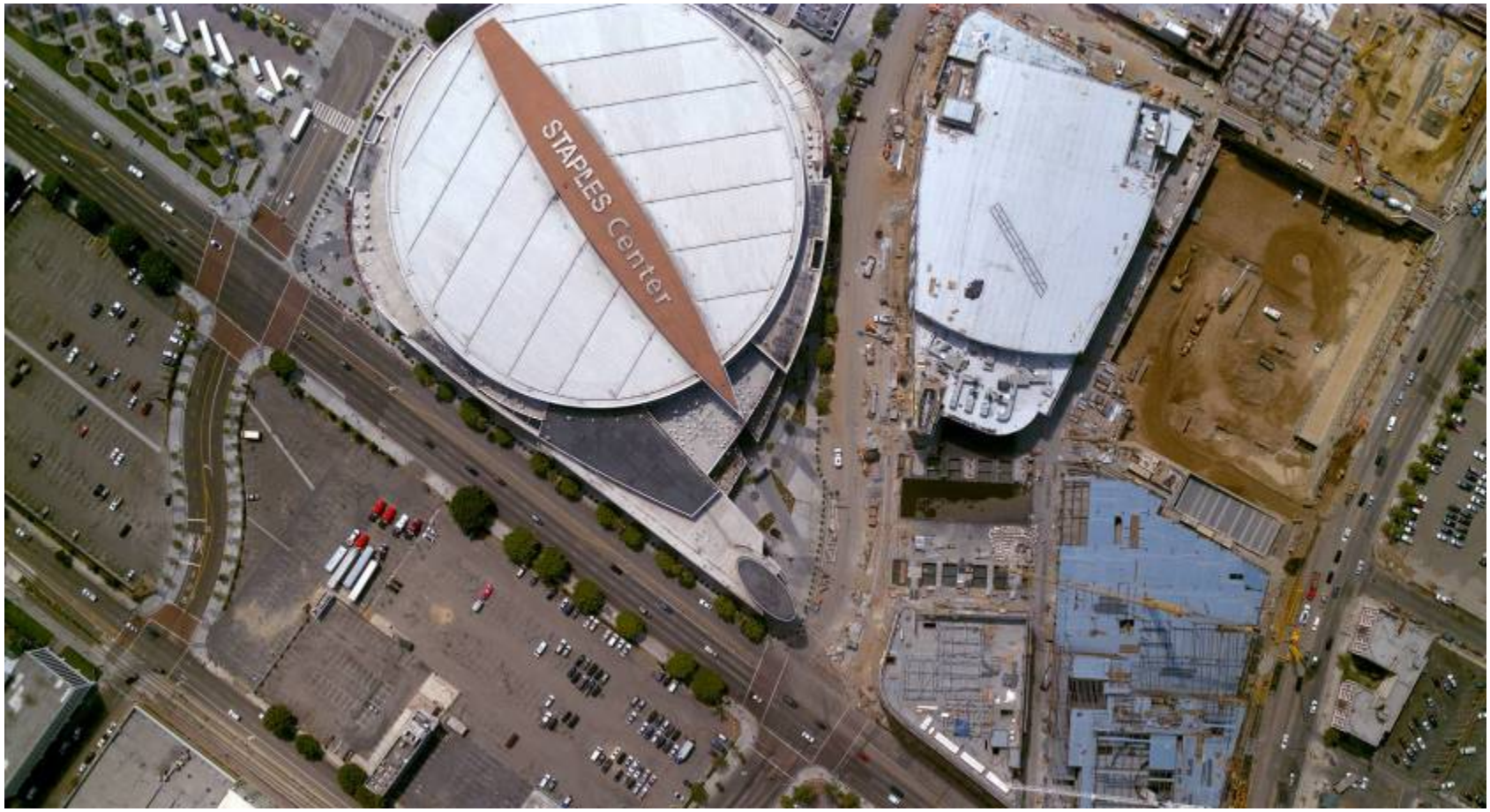
Images courtesy of IK Curtis Services, Inc.

RCD105 Digital Frame Camera for ALS LIDAR

rugged design for precise imagery



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RCD105 Digital Frame Camera for ALS LIDAR

rugged design for precise imagery

Application data summary
RCD105 lens selections

Focal Length (mm)	at 1000 m AGL flying height		at all flying heights	
	GSD (m)	Coverage (m)	FOV (degrees)	b/h (@ 60% FOL)
35	0.194	1391 x 1047	69.7 x 55.3	0.43
60	0.113	812 x 611	44.2 x 34.0	0.25
100	0.068	487 x 366	27.4 x 20.8	0.15

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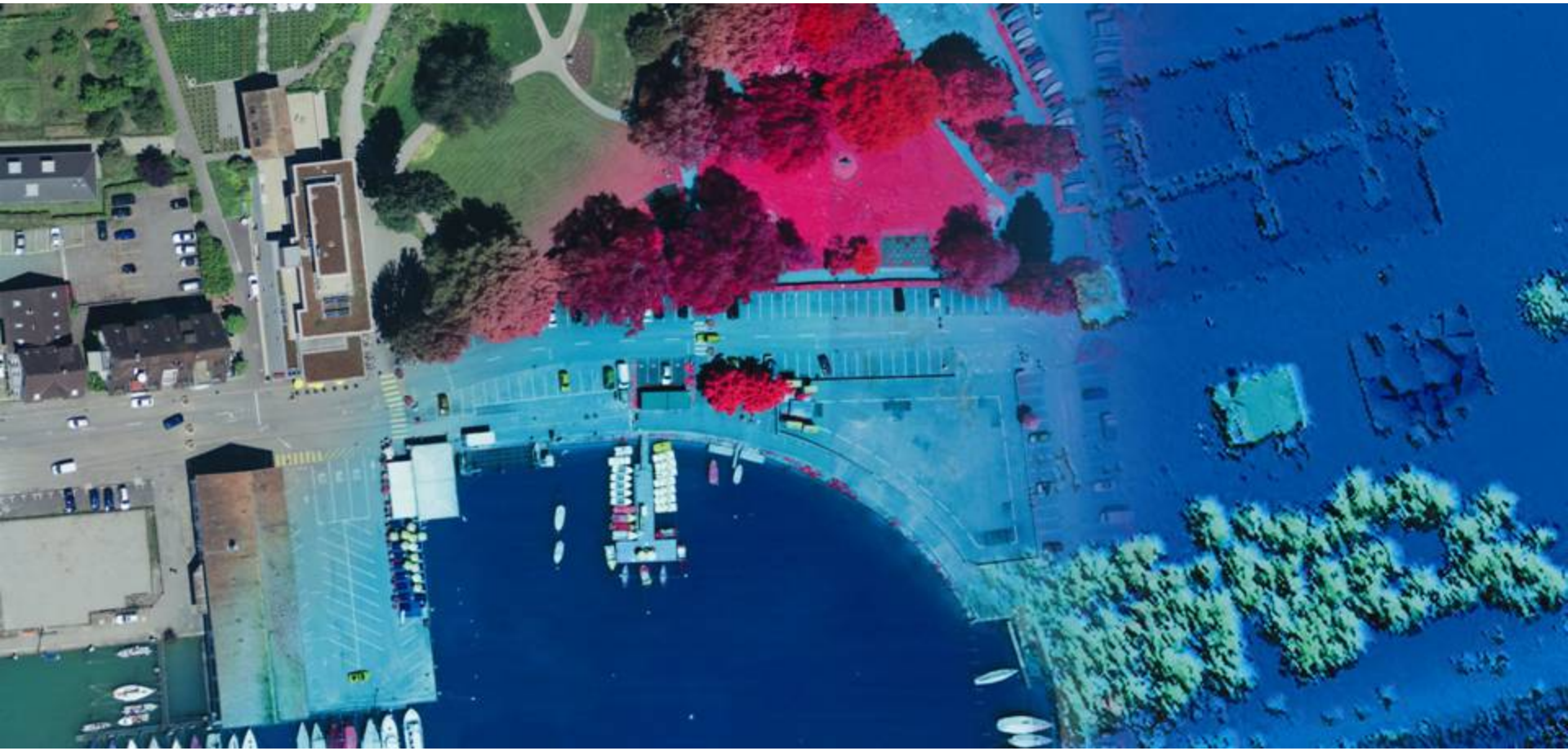
ADS80 Third Generation Sensor



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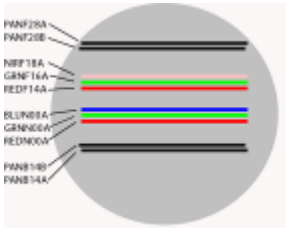
ADS40 1st & 2nd Generation – achievements

ADS40 1st Generation (2000-2006)

1 Sensor Head: SH40

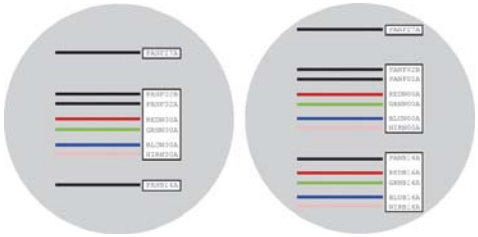


1
Focal
Plate
+
1 IMU

ADS40 2nd Generation (2007)

2 Sensor Heads: SH51 & SH52

2
standard
Focal
Plates
+
4 IMU's



		NUS4	DUS5	NUS5	CUS6
Absolute accuracy after post-processing (RMS)	Position	0.05 - 0.3 m	0.05 - 0.3 m	0.05 - 0.3 m	0.05 - 0.3 m
	Velocity	0.005 m/s	0.005 m/s	0.005 m/s	0.005 m/s
	Roll & Pitch	0.008 deg	0.005 deg	0.005 deg	0.0025 deg[1]
	Heading	0.015 deg	0.008 deg	0.008 deg	0.005 deg[1]
Relative accuracy	Angular random noise	< 0.05 deg/sqrt(hour)	< 0.01 deg/sqrt(hour)	< 0.01 deg/sqrt(hour)	< 0.01 deg/sqrt(hour)
	Drift	< 0.5 deg/hour	< 0.1 deg/hour	< 0.1 deg/hour	< 0.01 deg/hour

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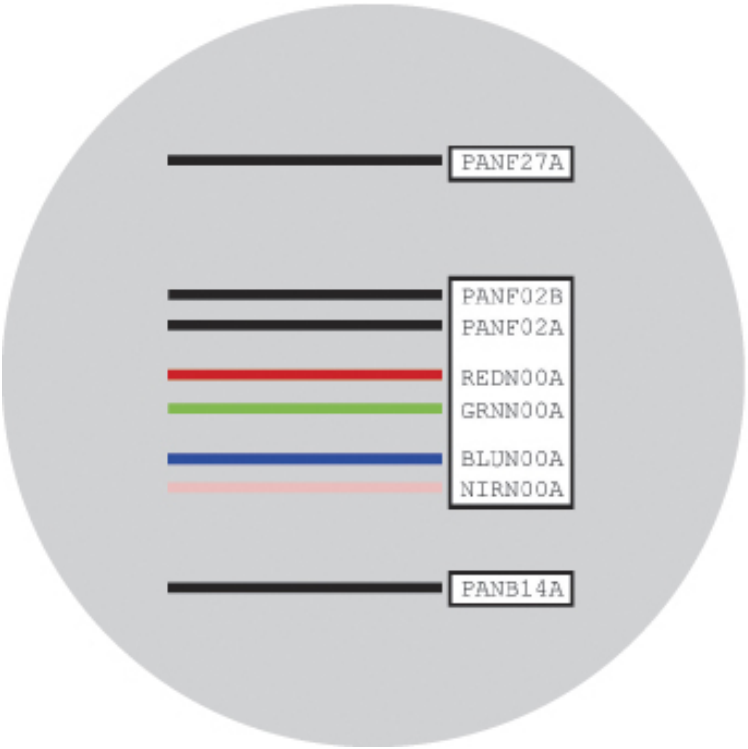
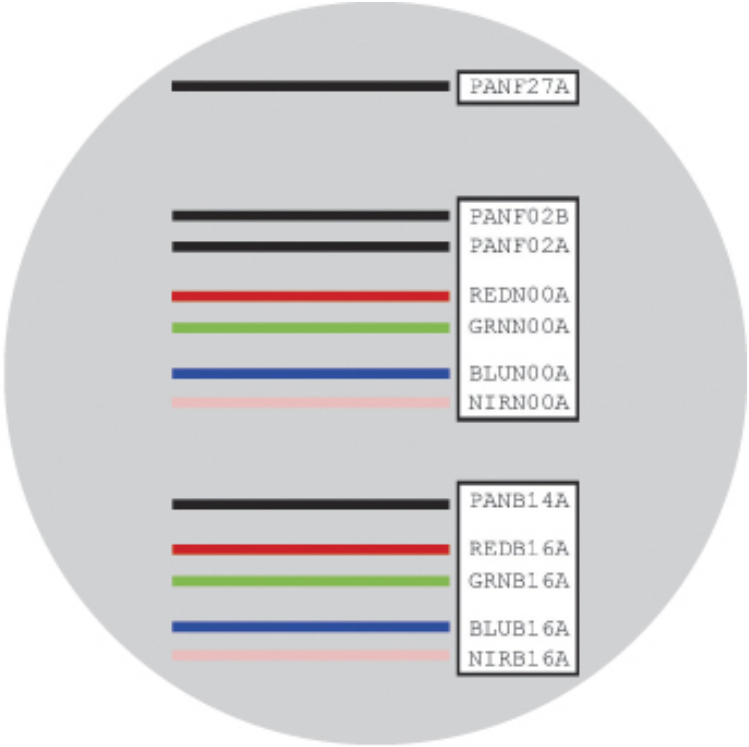
ADS40 2nd Generation
CCD layout

SH51 focal plate



SH52 focal plate



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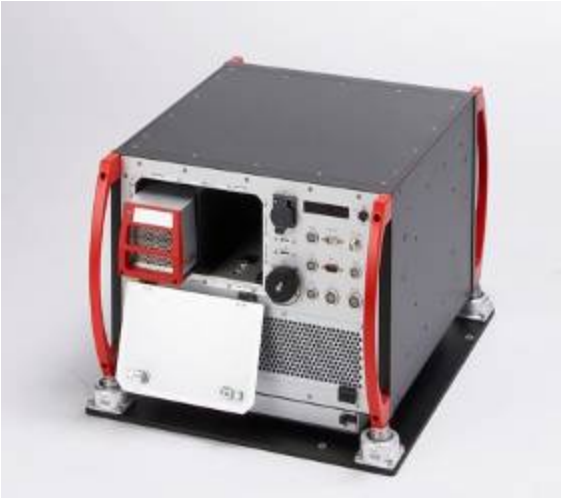
Leica ADS80 – Third Generation Achievements

Control Unit CU80 and MM80



- Embedded IPAS20 with GNSS
- High data throughput of 130 MB/sec
- Radiometric resolution of compressed data 10-bit and 12-bit,
- Recording interval ≥ 1 ms
- Data modes: ADS80 data format, raw data, compressed

- Highly reliable flash disk technology
- 364 GB / 768 GB capacity per MM80 pair
- Weight 2.5 kg

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Leica ADS80 – Consistent Technical Performance

GSD 1.2“ / 3 cm => 90 kts

GSD 2“ / 5 cm => 140 kts

GSD 3“ / 7.5cm => 190 kts

GSD 4“ / 10cm => 240 kts

GSD 6“ / 15cm => 300 kts

- 384 GB for up to ~5.7 h recording at 2.5 ms with 3 pan and 4 spectral bands
- 768 GB for up to ~11.4 h recording at 2.5 ms with 3 pan and 4 spectral bands

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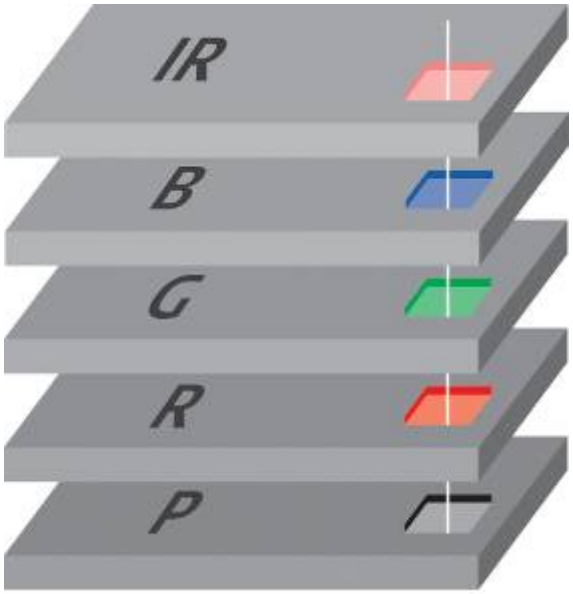
ADS80

Benefits of the Tetrachroid beamsplitter

- Perfectly co-registered **R,G,B,N** images
- All bands acquired at the same **native** resolution
- RGB and RGN composites with **same resolution** as the 3-line Pan images
- **No** Pan-sharpening required
- 5th band (Pan) from combined RGB bands
- Direct geo-referencing of **all** image data due to rigid connection of IMU, Focal plate, Tetrachroid and Optics



5-Band Imagery

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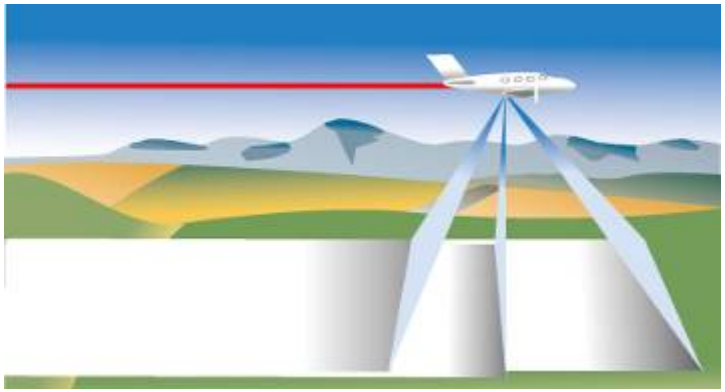
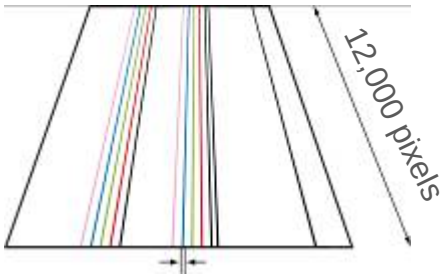
Advantages of the Three-Line Principle



1 lens, 1 focal plate,
12 CCD lines, 0 shutters

2 x Red
2 x Green
2 x Blue
2 x NIR
4 x Panchromatic



over large format patched frame cameras:

- **Same resolution in all bands**
  No pan-sharpening !
- **100% forward overlap**
- **Complete spectral band separation**
- **Superior color continuity in mosaics**
- **No defective pixels**
- **Superior Base/Height ratio**
- **No shutters, no FMC**
- **Single robust, accurate lens**
- **One focal plate**

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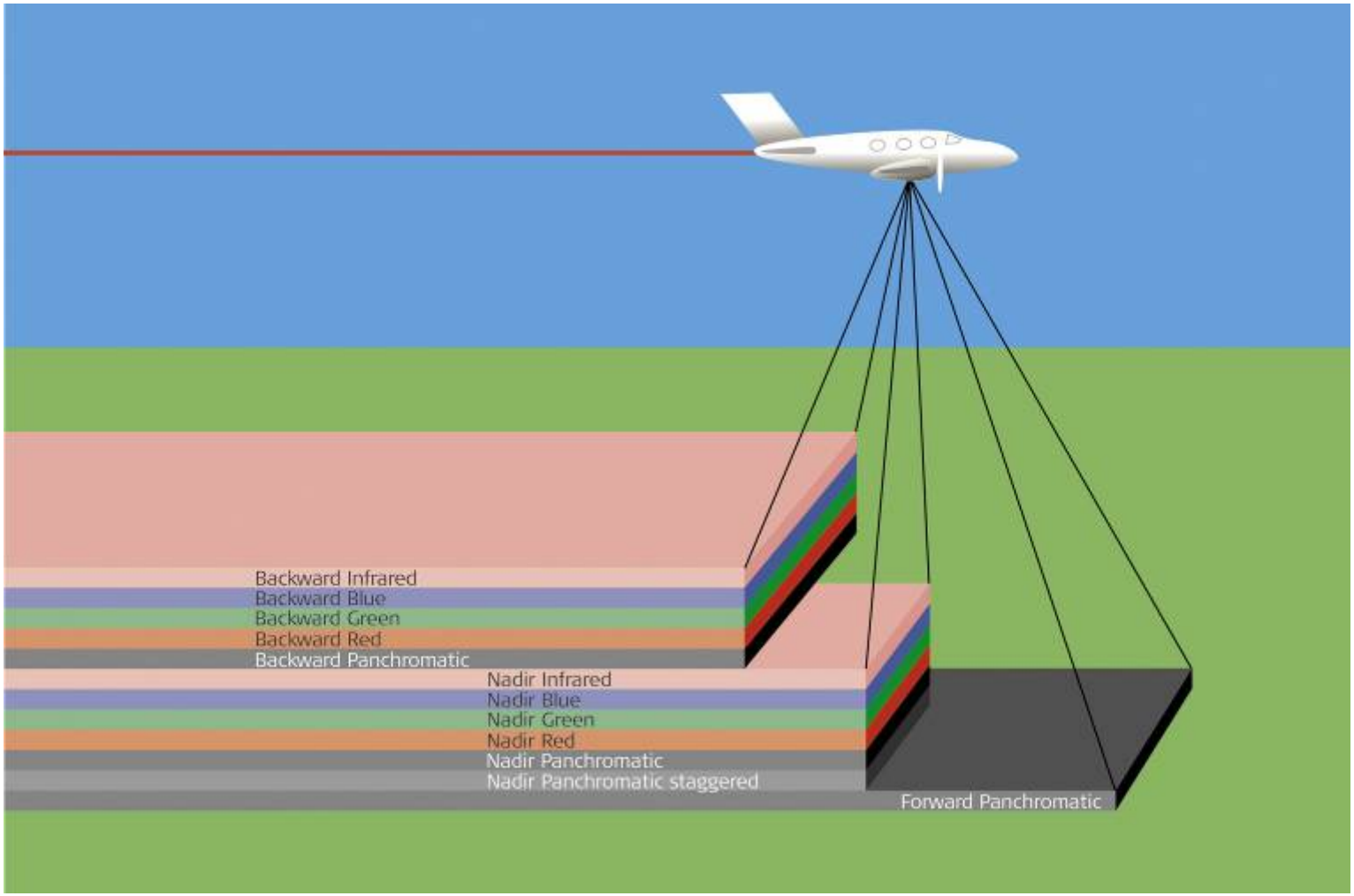
Panchromatic, RGB and NIR bands



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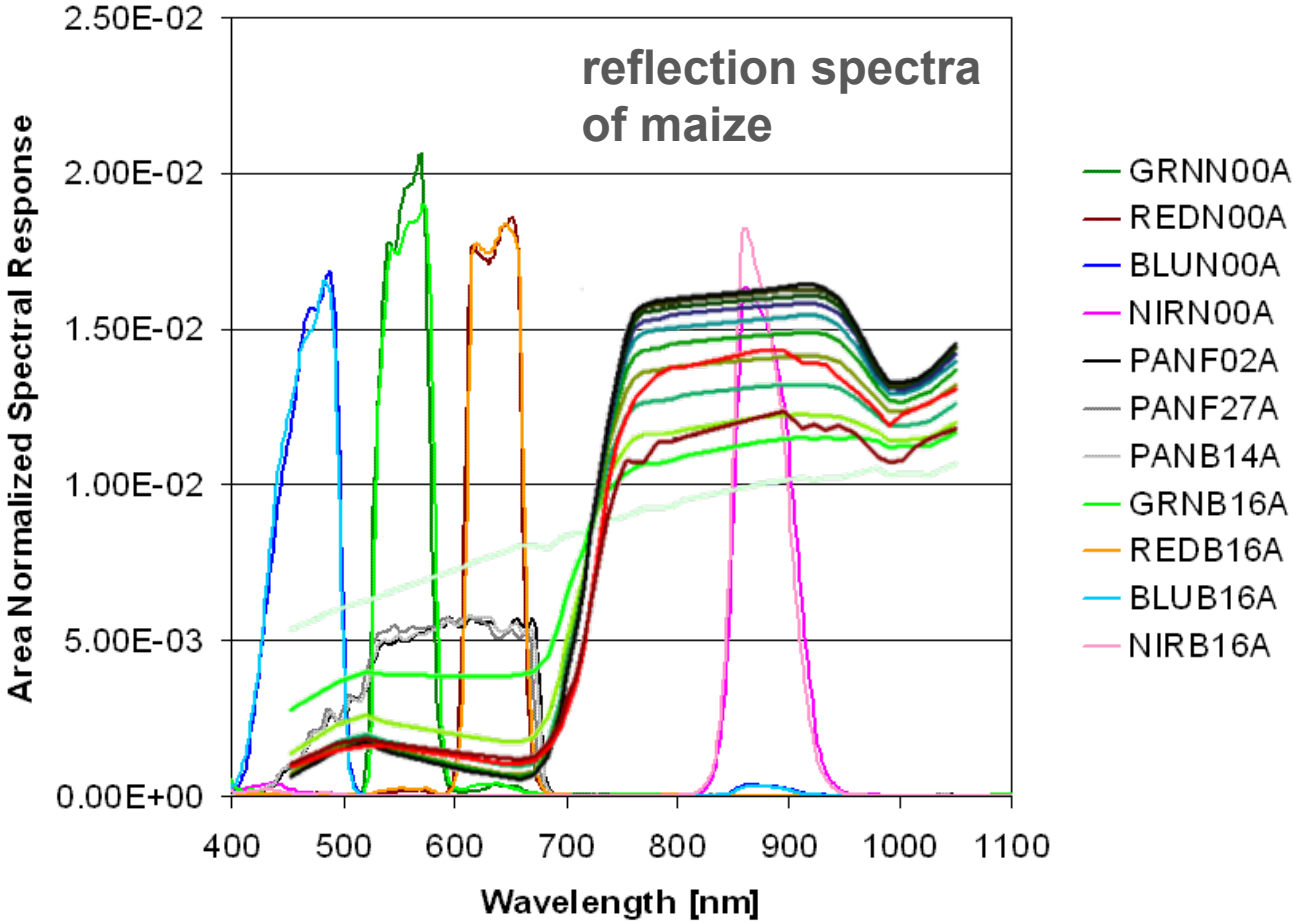
Co-registered RGB and NIR for remote sensing, optimized for vegetation



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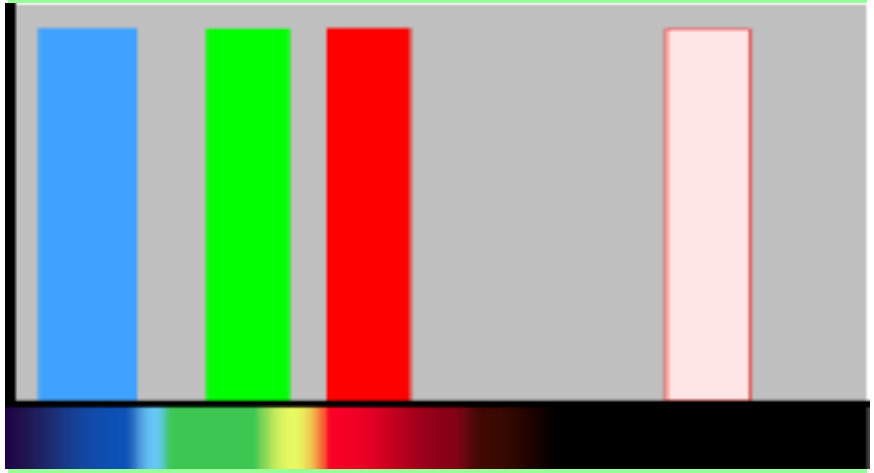
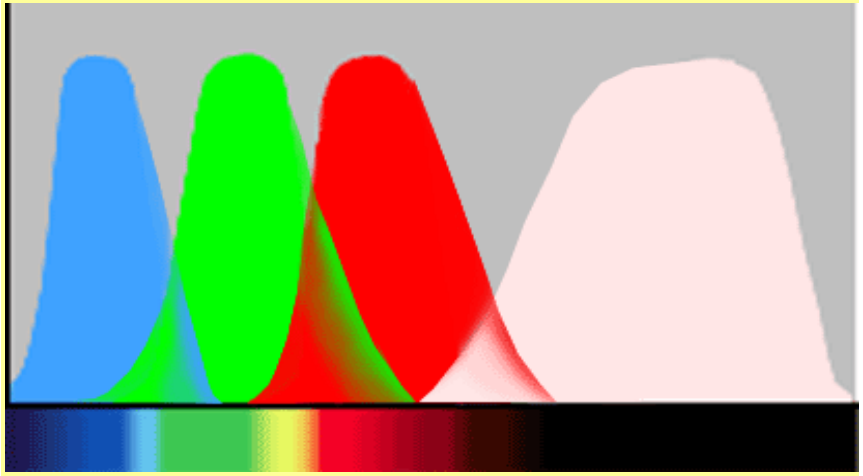
ADS80

Maintaining filter transmission characteristics

Interference filters Used in ADS40	Absorption filters Used in CCD array cameras
Non-overlapping narrow bands	Overlapping bands





Interference filters are best for remote sensing applications where response in non-overlapping narrow bands is required

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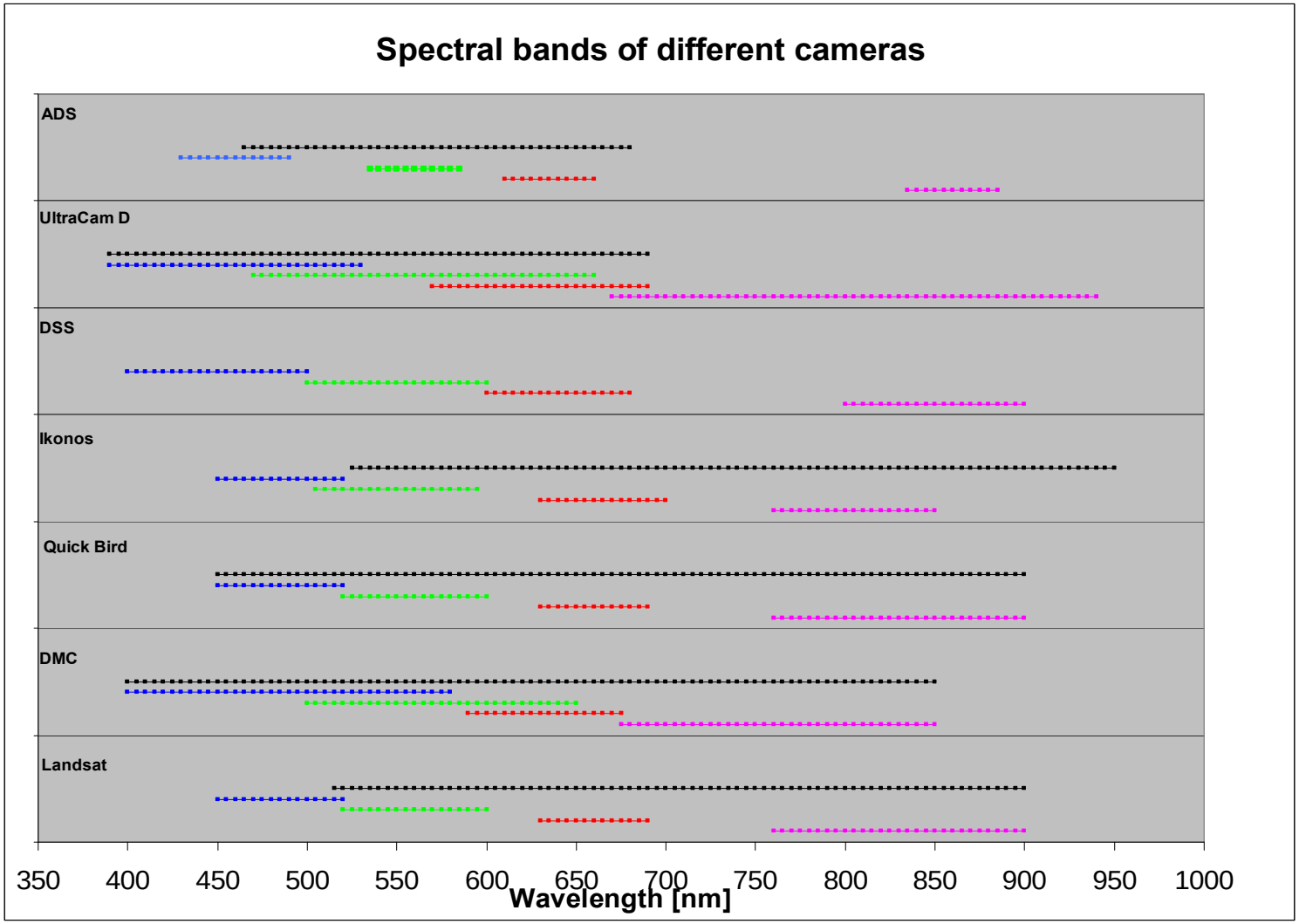
ADS80

Separate bands for Remote Sensing



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ADS40 2nd Generation – the airborne sensor solution for large area forestry mapping?

Contents

- **Technology – the ADS40 2nd Generation hardware**
- **OMNR (Ontario Ministry of Natural Resources) Project**

Description

- **Outlook**

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Project Purpose

- To update the forest inventory base map that is then used as the foundation layer for the next 10 year cycle.
- The plan is to repeat this process every 10 years with smaller sample areas done from year to year.

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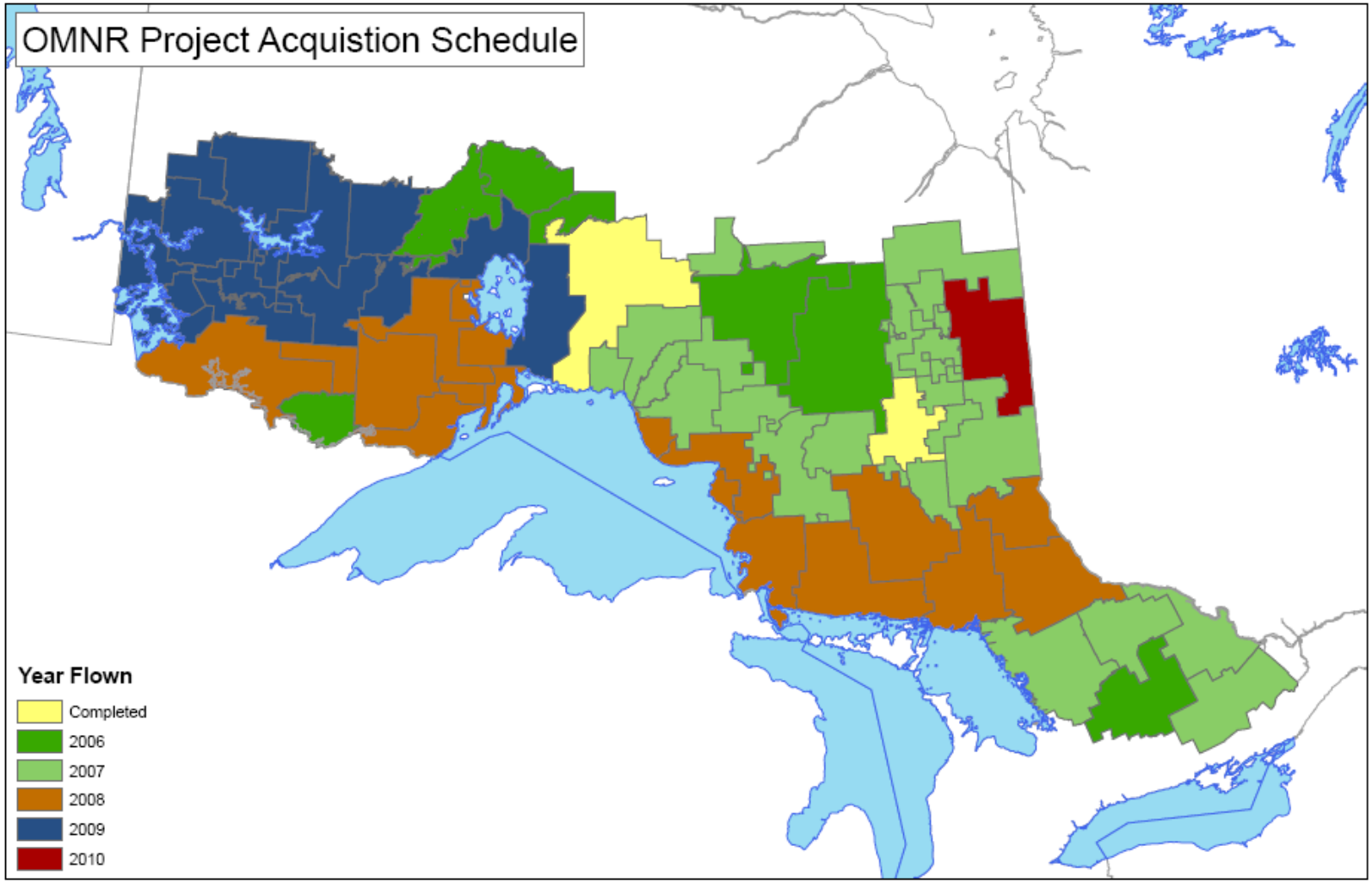
Project Size



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Project Size

- ~600,000 sq/km
- over a 5 year period of the forestry region of the province of Ontario
- all at 20cm resolution

Biggest project of its kind…….ever!

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Deliverables

This project is using everything that can be created by the ADS40 2nd Generation:

For remote sensing/interpretation:

- 20cm 4 band L1 stereo imagery, 16 bit
- 20cm 4 band ortho products, 16 bit
- 20cm Panchromatic L1 stereo products, 16 bit
- 20cm Panchromatic ortho products, 16 bit

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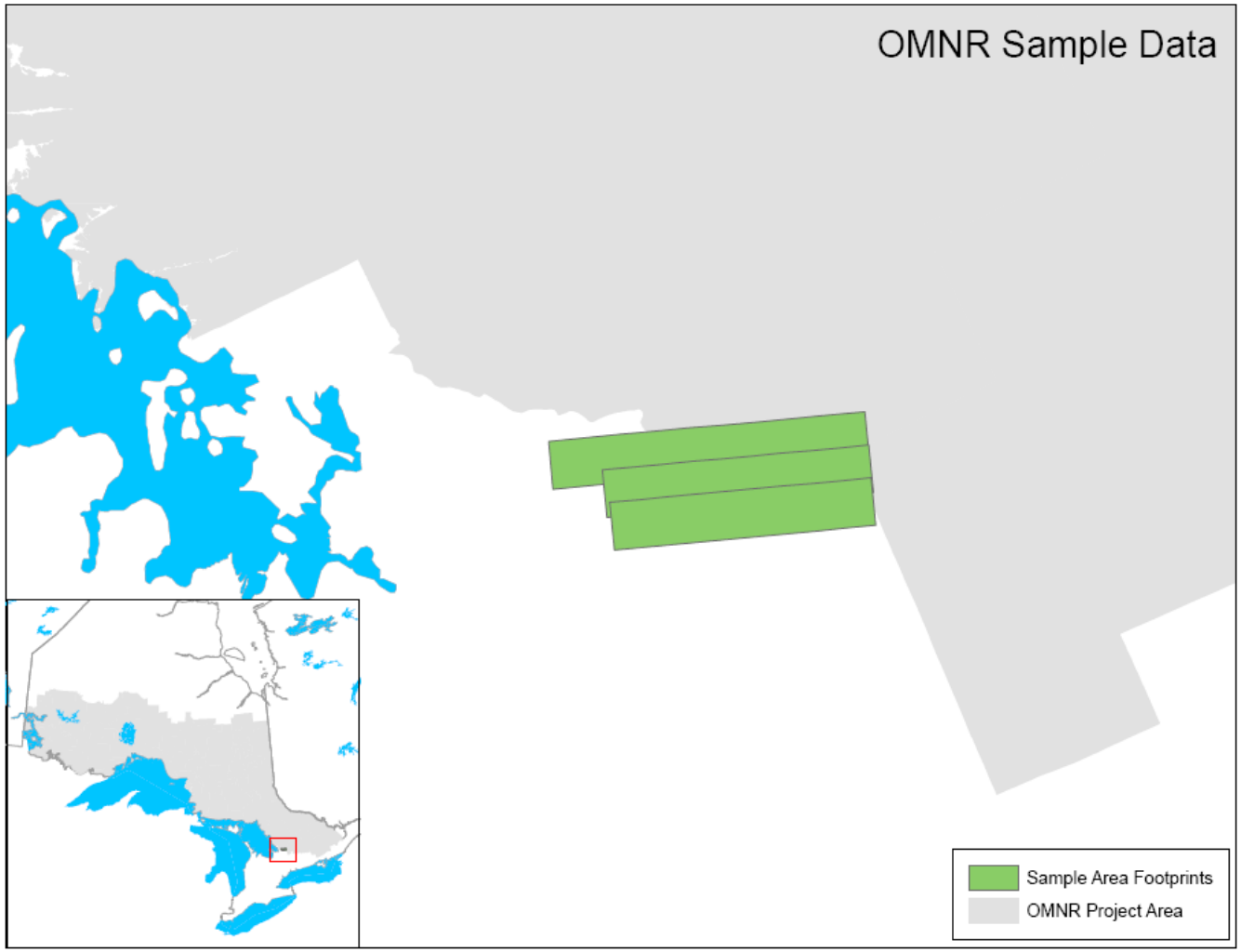
OMNR Example Data



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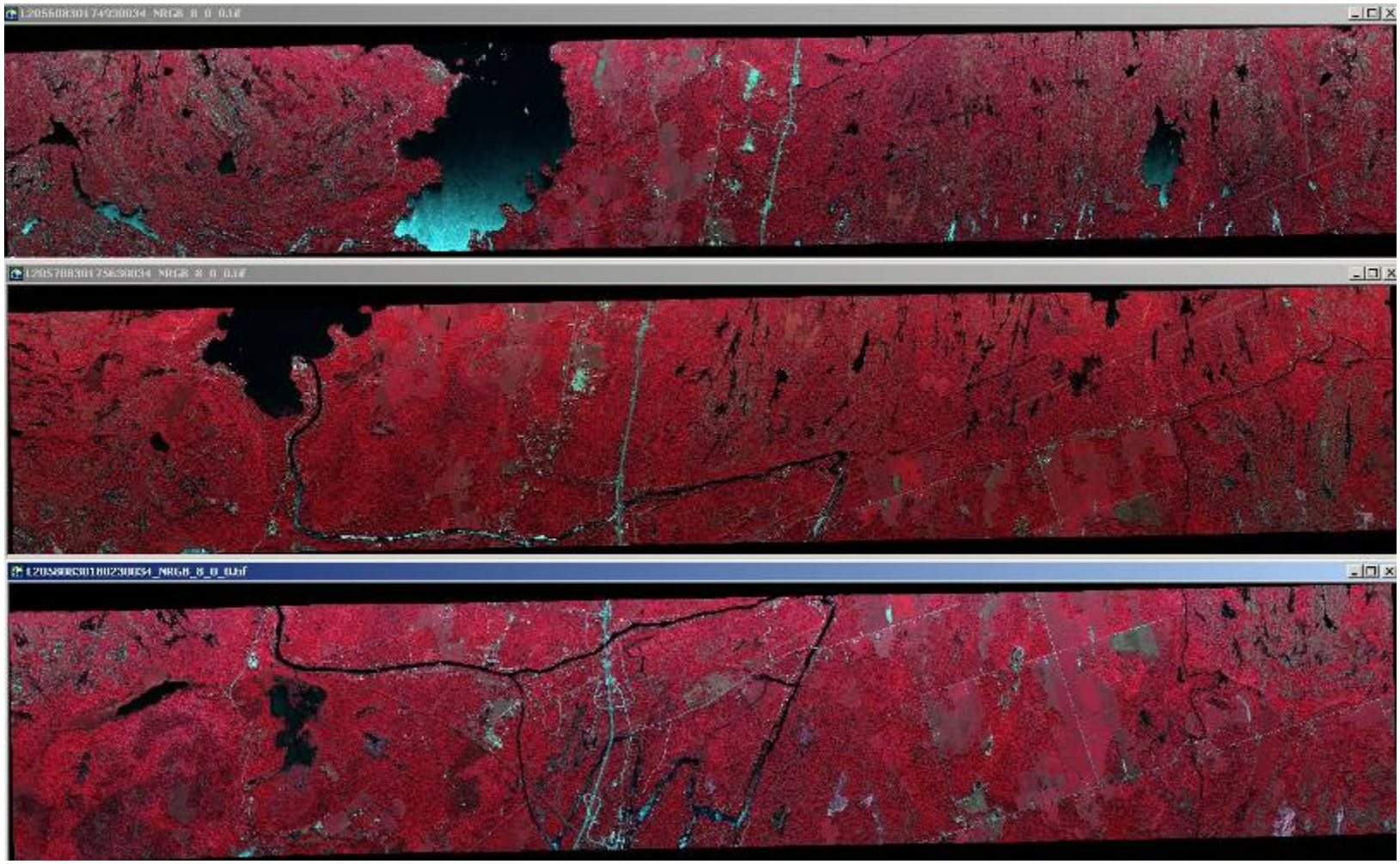
Three Pixel Carpets



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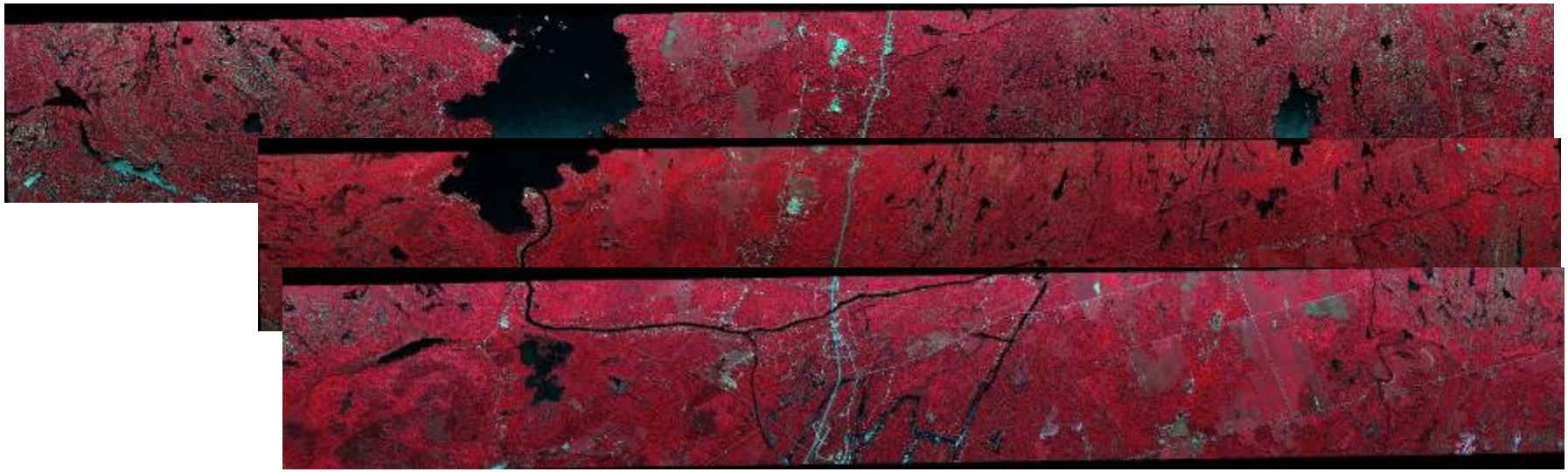

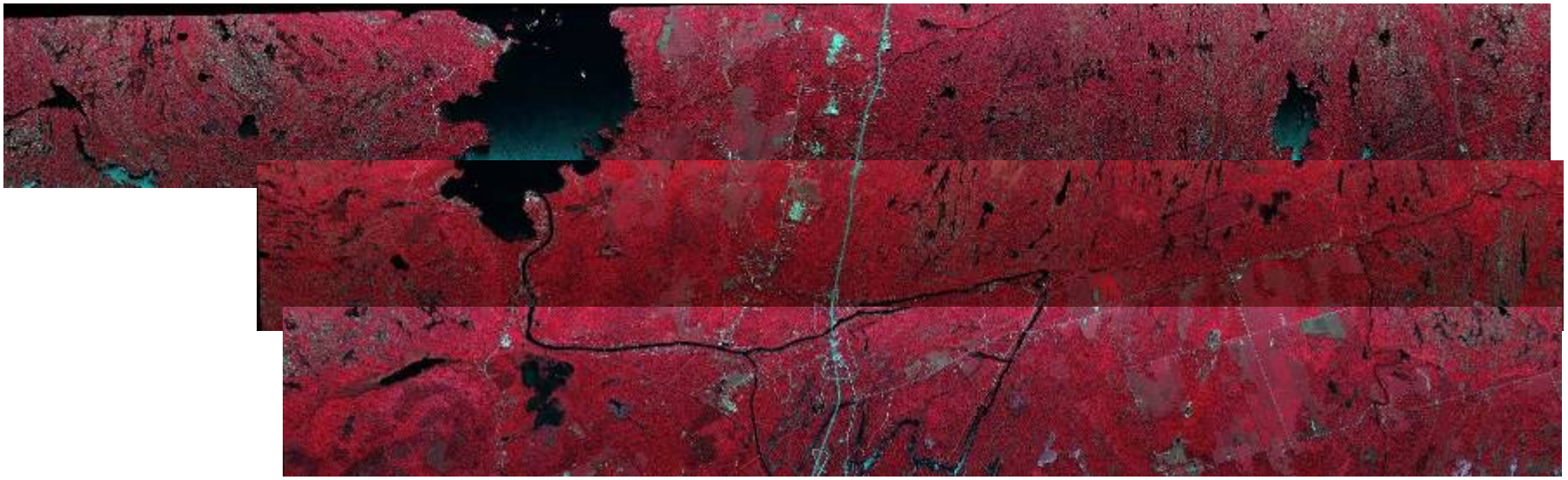

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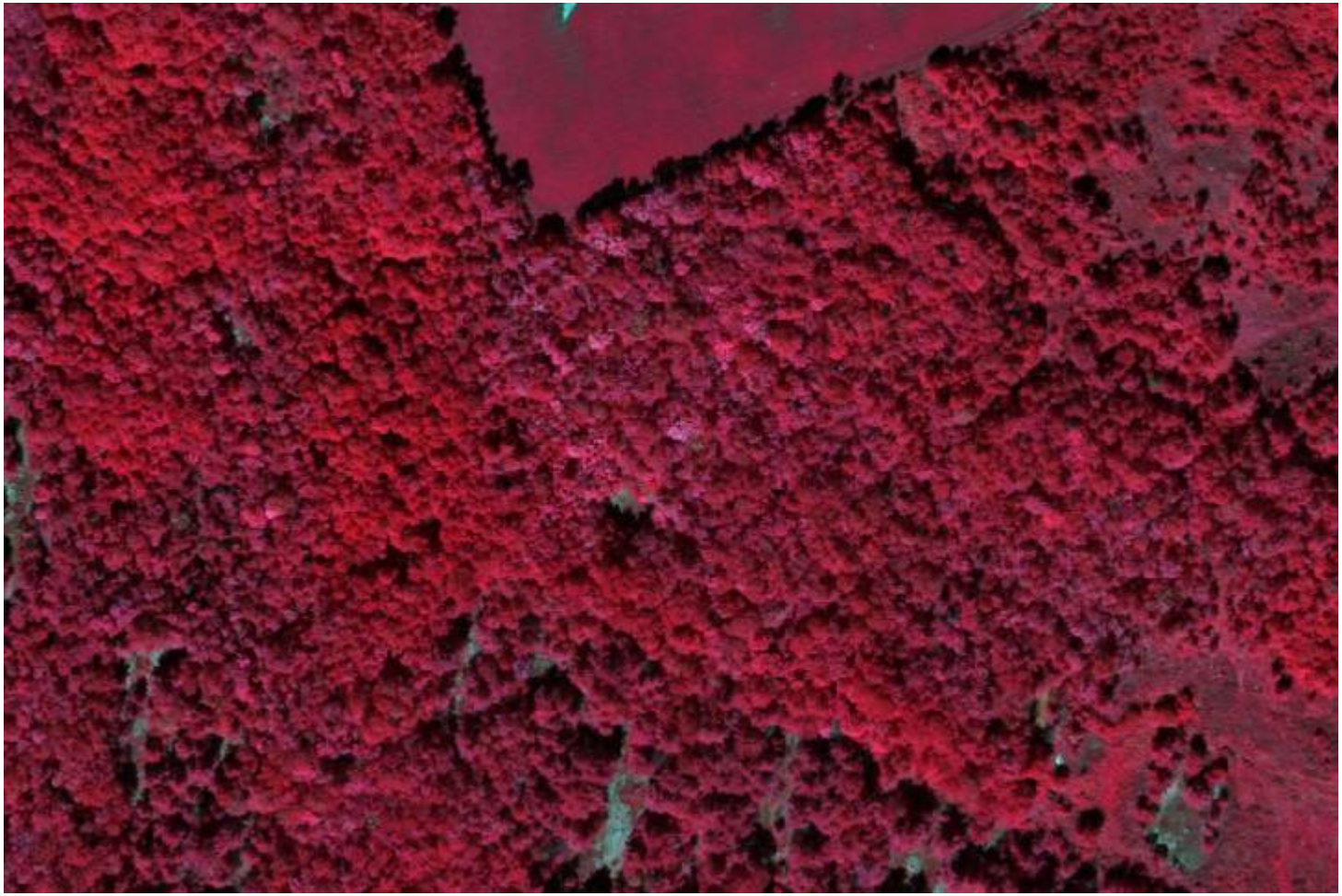
OMNR Example Data L2



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Future Work and Expectations

- Stereo products will be used to do stereo digitizing of the forest stands.

- Raw L2 ortho strips will be used for automated processing to identify water and dead forest areas.

- Over the program, it is hoped that more automation can be introduced to start to remove the stereo digitizing of the forest stands and species identification.

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„The ADS40 2nd Generation…..

…….was the only sensor that could be used, as pan sharpening degrades the spectral resolution too much to allow good interpretation and automated results.”

John Welter, NWGeo

6-inch ADS40 imagery draped over a DTM

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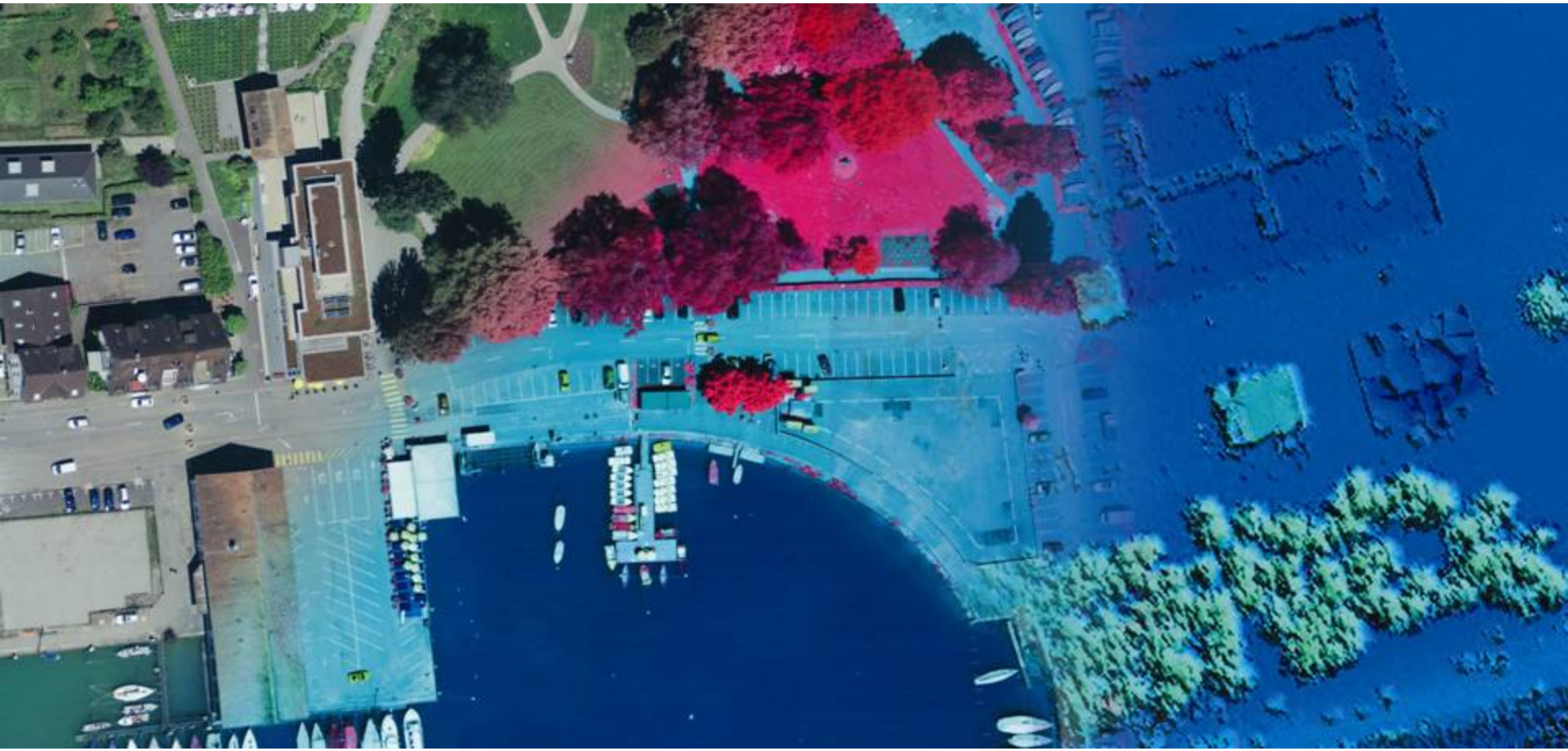
Example Data – Luzern, Switzerland

…nice pictures but can you map from them?



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ADS40 Map Accuracy Test

•Vertical accuracy is the principal criterion in specifying the quality of digital elevation data, and vertical accuracy requirements depend upon the intended user applications

•There are five principal applications where high vertical accuracy is normally required of digital elevation datasets: (1) for marine navigation and safety, (2) for stormwater and floodplain management in flat terrain, (3) for management of wetlands and other ecologically sensitive flat areas, (4) for infrastructure management of dense urban areas where planimetric maps are typically required at scales of 1 inch = 100 feet' and larger scales, and (5) for special engineering applications where elevation data of the highest accuracy are required.

•If vertical error is normally distributed, the factor 1.9600 is applied to compute linear error at the 95% confidence level (Greenwalt and Schultz, 1968). Therefore, vertical accuracy, Accuracyz, reported according to the NSSDA shall be computed by the following formula:

- Accuracyz = 1.9600 *RMSEz.

NMAS Equivalent Contour Interval	NMAS VMAS 90 percent confidence level Maximum Error Tolerance	NSSDA $RMSE_z$	NSSDA $Accuracy_z$, 95 percent confidence level
1 ft	0.5 ft	0.30 ft or 3.6 in or 9.25 cm	0.60 ft or 7.2 in or 18.2 cm
2 ft	1 ft	0.61 ft or 7.32 in or 18.5 cm	1.19 ft or 14.28 in or 36.3 cm
4 ft	2 ft	1.22 ft or 37.0 cm	2.38 ft or 72.6 cm
5 ft	2.5 ft	1.52 ft or 46.3 cm	2.98 ft or 90.8 cm
10 ft	5 ft	3.04 ft or 92.7 cm	5.96 ft or 1.816 m
20 ft	10 ft	6.08 ft or 1.853 m	11.92 ft or 3.632 m
40 ft	20 ft	12.16 ft or 3.706 m	23.83 ft or 7.264 m
80 ft	40 ft	24.32 ft or 7.412 m	47.66 ft or 14.528 m

Table 2 Comparison of NMAS/NSSDA Vertical Accuracy

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ADS40 Map Accuracy Test

- **The ADS40 SH/52 was flown in a Cheyenne-II twin engine prop over a heavily controlled area (Jefferson County Airport)**
- **The RMSE of the AT was:**
  - X = 0.0198 ft
  - Y = 0.0176 ft
  - Z = 0.0094 ft
- **Using the National Standard for Spatial Data Accuracy, the data set tested 0.69 foot vertical accuracy at 95% confidence level.**
- **Using the National Standard for Spatial Data Accuracy, the data set tested 0.77 foot horizontal accuracy at 95% confidence level.**

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Not only will it do NAIP work…
but it is accurate enough for large scale mapping

NSSDA Horizontal & Vertical Accuracy Statistic Worksheet

XY Only | Show Control | Show Tested | Show All | Show Control Only | Hide All Stats | Show Pt Info | Show Z
Z Only | Hide Control | Hide Tested | Hide Pt Info | Hide Z

Version: 20080227

To ADD rows, insert them beneath column headings or inside the table.

	Point Information		Control			Tested or Measured			Statistics						
Point			X	Y	Z	X	Y	Z	X	X	Y	Y	XY	Z	Z
number	Point description	Testing Comments			Control			Tested	diff in x	(diff in x) 2	diff in y	(diff in y) 2	(diff in x)2 + (diff in y)2	diff in Z	(diff in Z)2
8167	TOP SW COR CONC		3107723.97	1758041.78	5619.89										
8168	CENTER END YELLOW STRIP		3108500.83	1758073.10	5610.94										
8169	SE COR CONC		3108329.81	1757799.59	5611.84										
8170	CENTER MH		3108313.41	1757815.68	5612.28										
8171	NE COR CONC		3108249.33	1757680.05	5612.05										
9031			3110734.93	1754475.22	5576.68	3110734.8	1754474.85	5576.18	0.13	0.02	0.37	0.14	0.15	0.50	0.25
												Count	24.00		24.00
												sum	4.74		3.00
												average	0.20		0.13
												RMSE	0.44		0.35
												NSSDA	0.77		0.69

Columns D-F: coordinates of points from independent data set or surveyed control
Columns G-I: coordinates of points measured in the mapping products
RMSE = sqrt of Average
NSSDA XY NSSDA accuracy statistic = 1.7308 * RMSE
NSSDA Z NSSDA accuracy statistic = 1.9600 * RMSE

Statistics: XY		Z
Count	24.00	24.00
sum	4.74	3.00
average	0.20	0.13
RMSE	0.44	0.35
NSSDA	0.77	0.69

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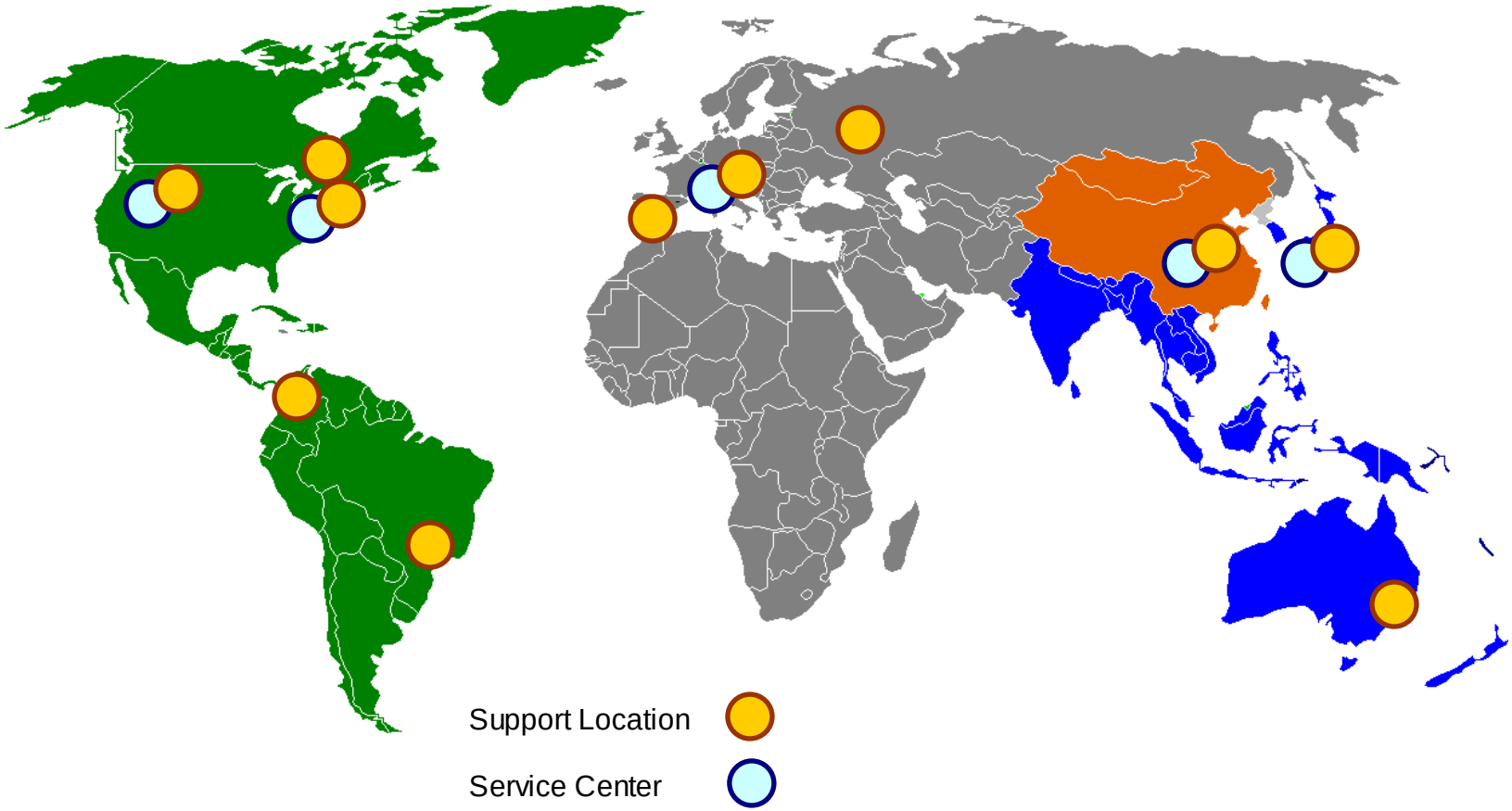
Global Service & Support Locations.



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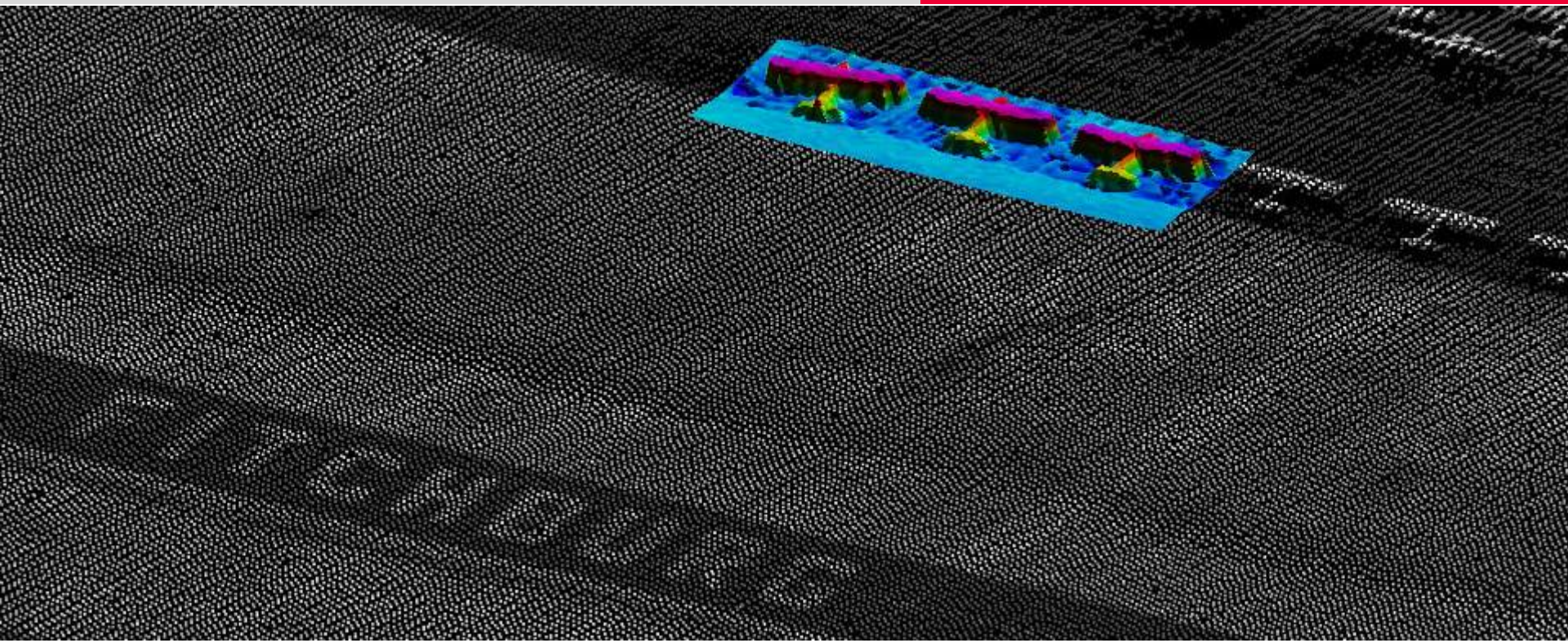

Thank You!

Shawn.slade@leicaus.com

303 799 9453 x 1913

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