Alaska Geographic Data Committee

Alaska Mapped

ALASKA STATEWIDE DIGITAL MAPPING INITIATIVE

Exploring Medium and High Resolution Commercial Imagery Solutions to Meet Statewide Mapping Needs in Alaska

Russ Cowart
i-cubed

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HDR
Baker

GOALS OF SDMI

- CREATE A BASE MAP OF ALASKA: Acquire imagery and digital elevation data necessary to meet specifications, generate ortho-imagery and DEMs, and assess accuracy of final products.

- CREATE THE ARCHIVE: Develop the project infrastructure to warehouse, archive and make products available to the public.

- LIFECYCLE MANAGEMENT OF THE BASE MAP DATA: Provide ongoing management of the base map data.

DEM COMPONENT

- Separate workshop and whitepaper
- www.alaskamapped.org
- DTED-2 for 1:24k NMAS image map
- Project based lidar
- IFSAR for Aviation Safety, detailed hydrology, costal erosion etc.
- Dave Maune from Dewberry is under contract to build state and federal consensus and get funding

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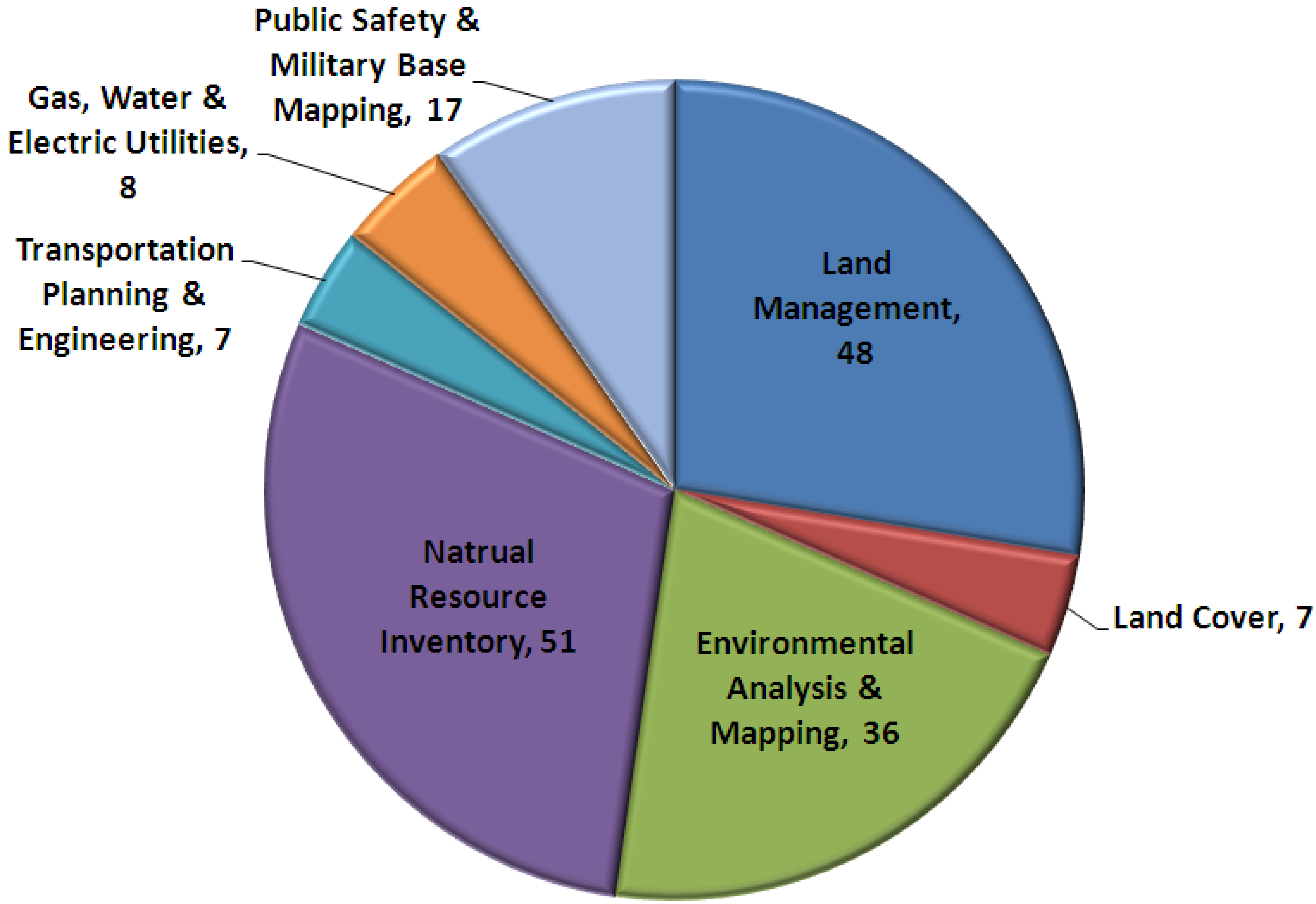
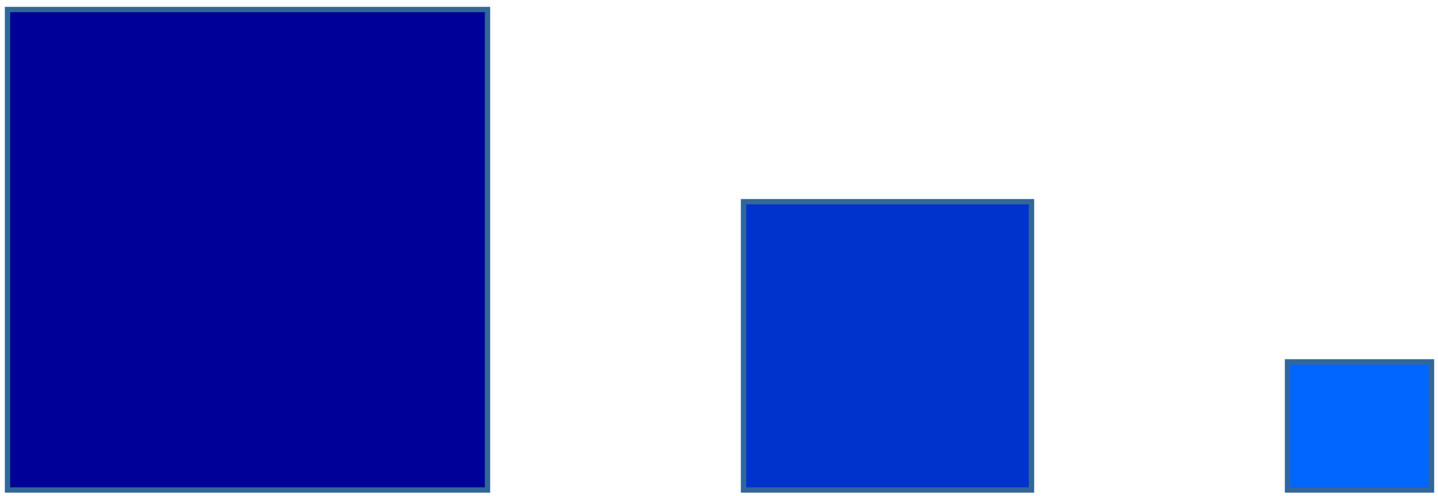
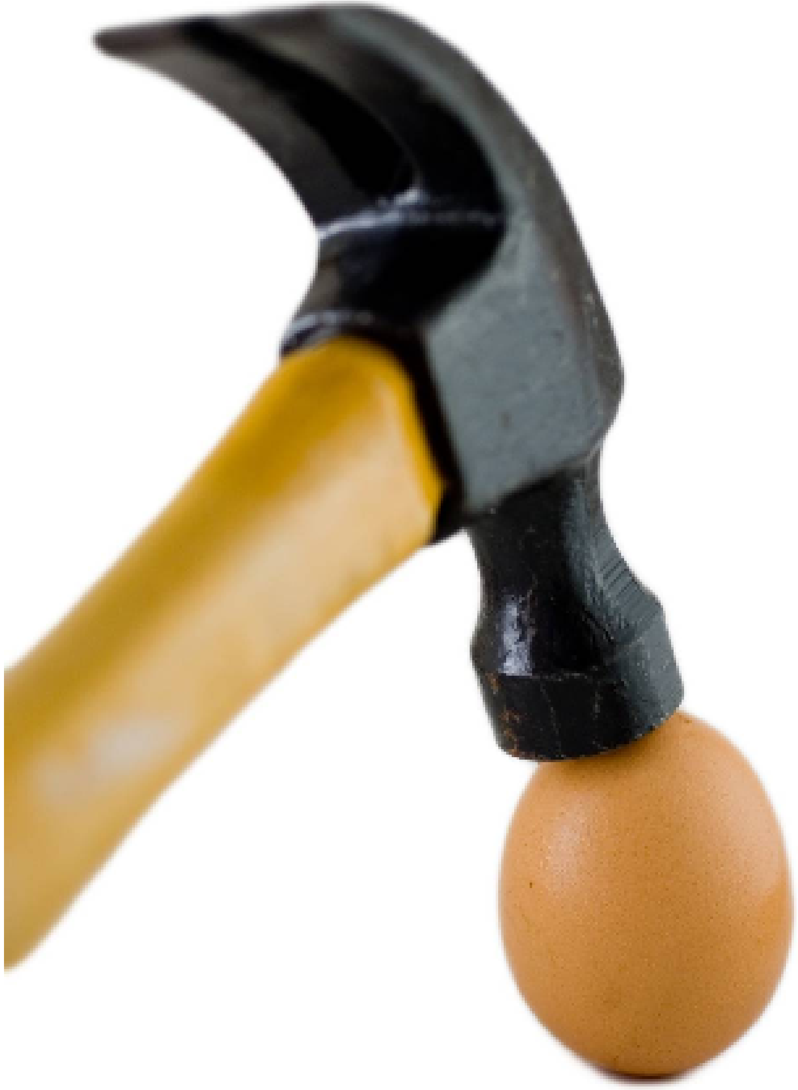

Public Safety & Military Base Mapping, 17
Gas, Water & Electric Utilities, 8
Transportation Planning & Engineering, 7
Land Management, 48
Land Cover, 7
Environmental Analysis & Mapping, 36
Natrual Resource Inventory, 51



Variable Resolution Needs



Beware of Overkill

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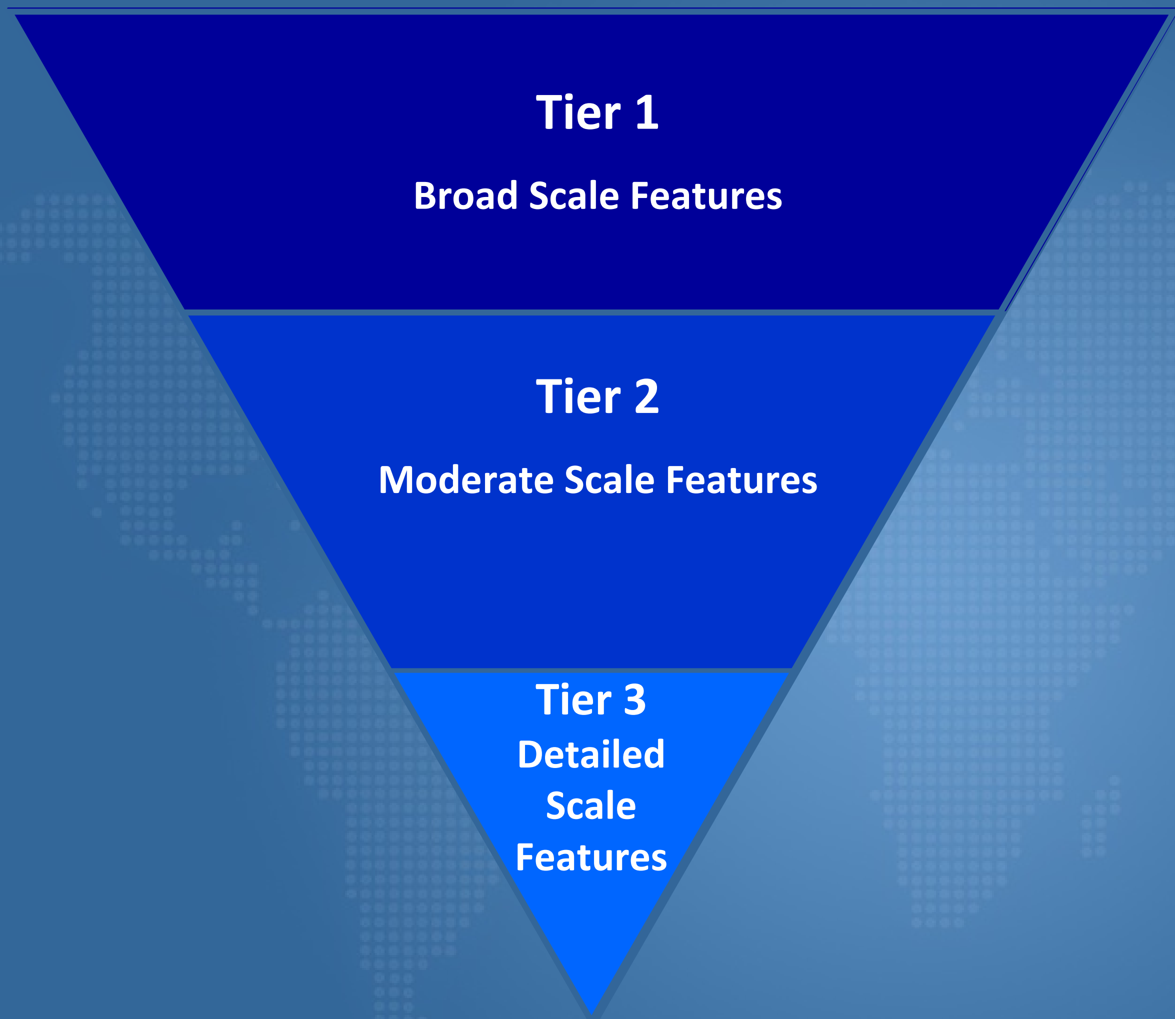
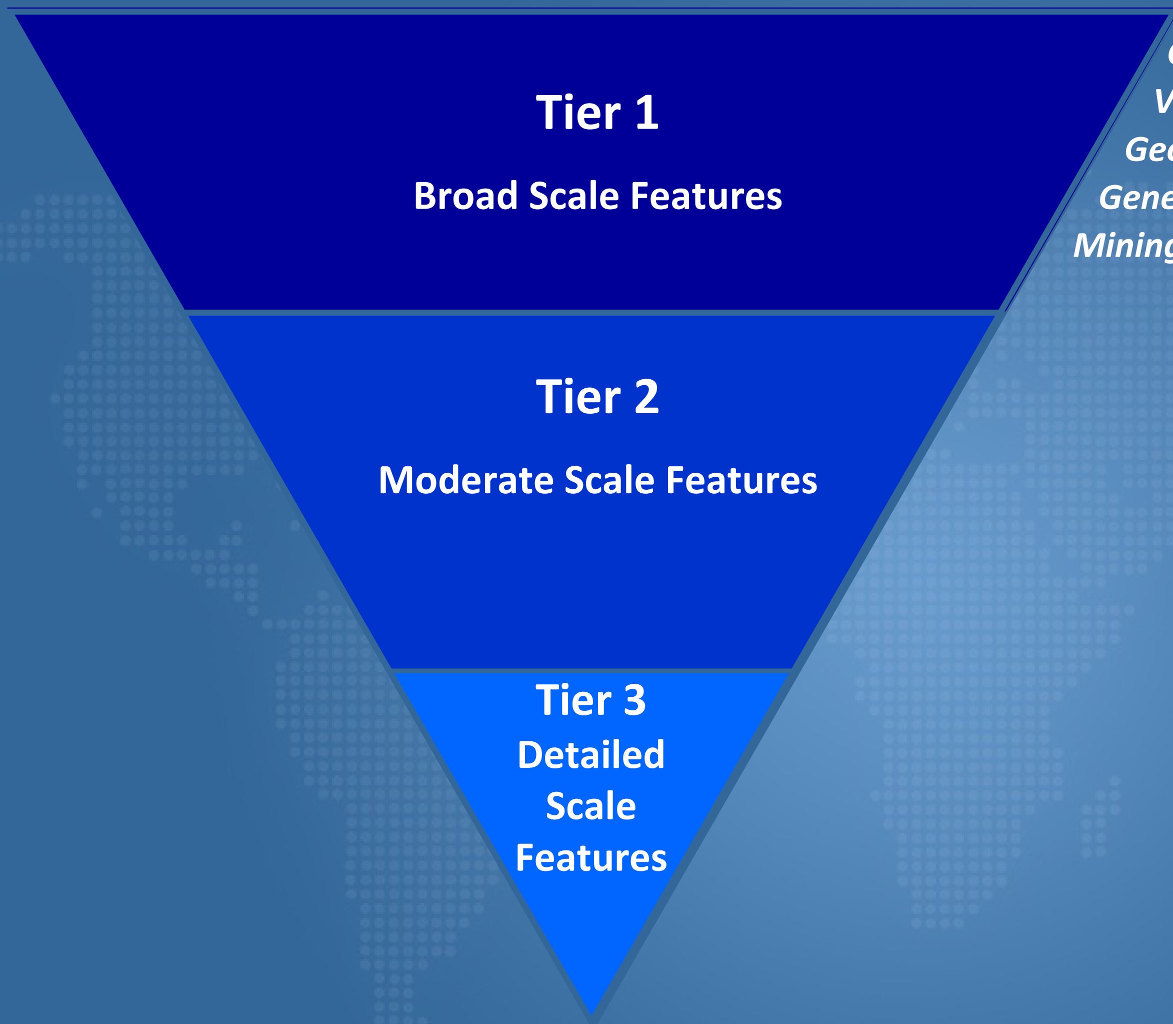
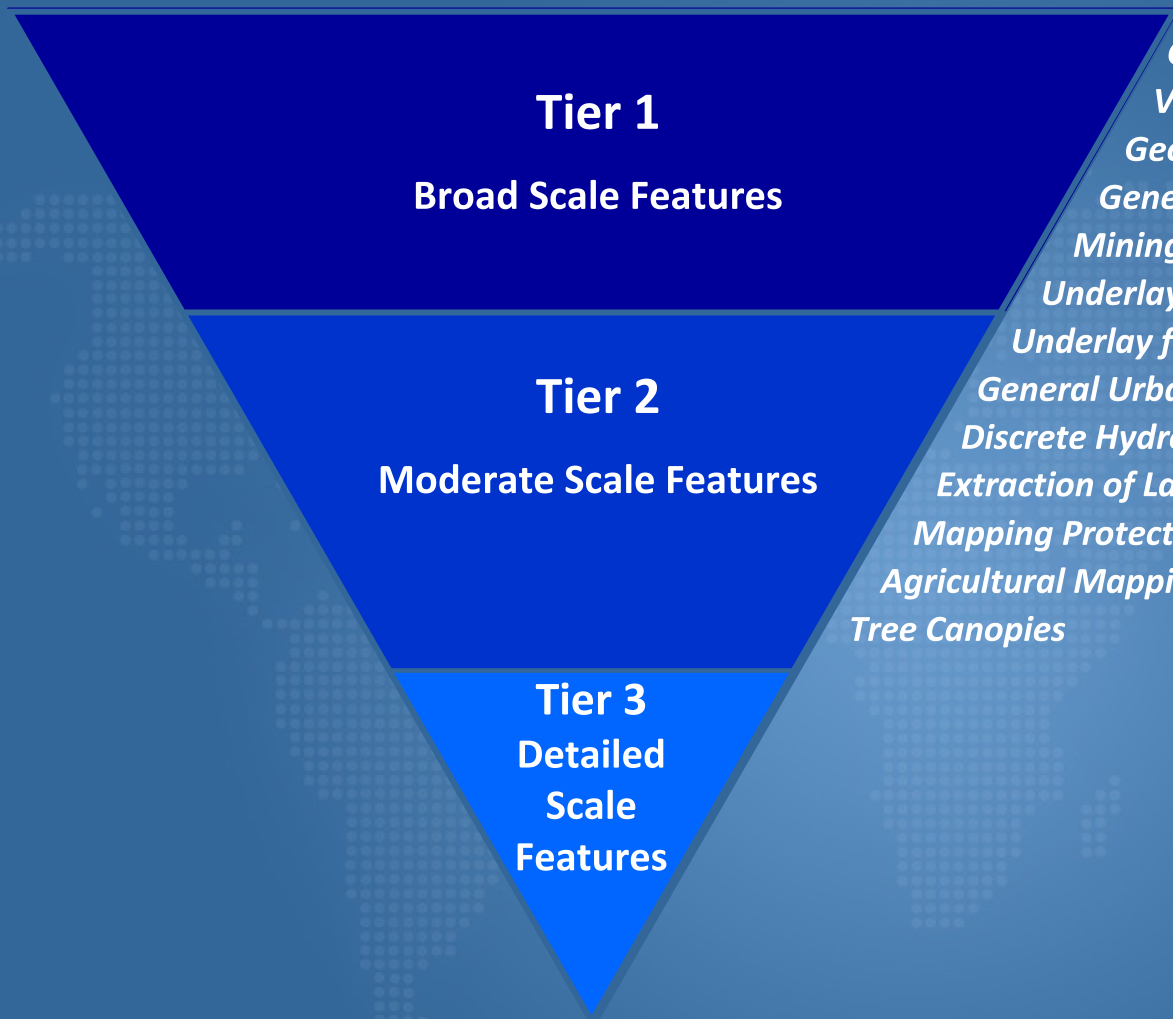

Tier 1
Broad Scale Features
Tier 2
Moderate Scale Features
Tier 3
Detailed
Scale
Features



- *Climate Change*
- *General Hydrographic Features*
- *Vegetation Land cover*
- *Geologic Unit Mapping*
- *General Wetlands Mappings*
- *Mining*

CONTENT DELIVERED



Climate Change
General Hydrographic Features
Vegetation Land cover
Geologic Unit Mapping
General Wetlands Mappings
Mining
Underlay for Parcel /Property Boundaries
Underlay for Land use & Natural Area Boundaries
General Urban & Rural Cover
Discrete Hydrographic Features (riverbanks/ponds)
Extraction of Land use & Natural Area Boundaries
Mapping Protected Areas & Trails
Agricultural Mapping & Monitoring
Tree Canopies

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Tier 1

Broad Scale Features

Tier 2

Moderate Scale Features

Tier 3

Detailed Scale Features

Climate Change
General Hydrographic Features
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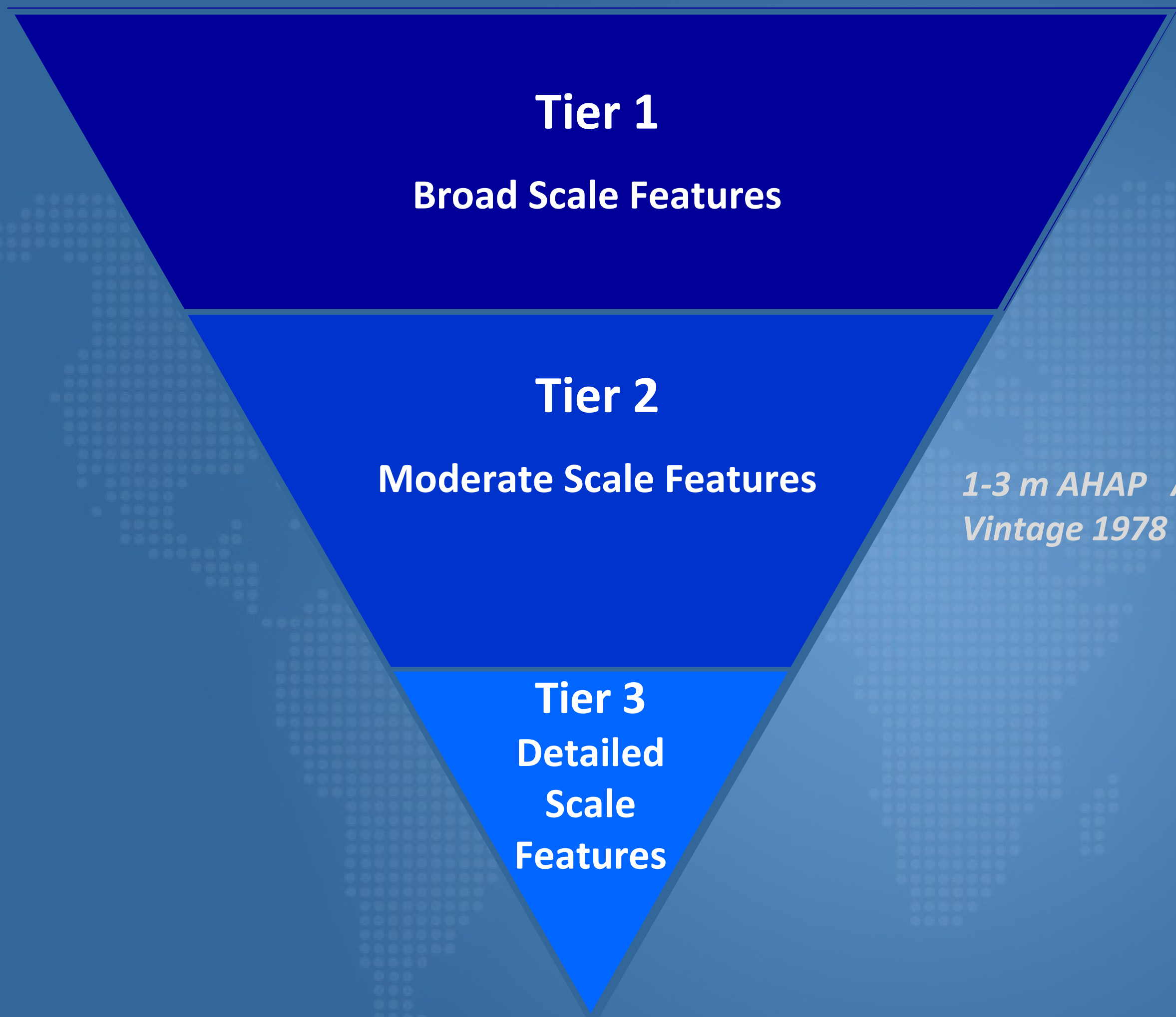
Agricultural Mapping & Monitoring
Tree Canopies
Discrete Wetlands Boundaries
Extraction of Parcel / Property Boundaries
Pipeline Mapping
Parking lots & impervious surface
Military Base Mapping
Major Road Intersections / Road Centerlines
Commercial & Household Building Footprints
Utilities (hydrants, electric power poles etc.)

15 – 30 m Landsat



1-3 m AHAP Alaska High Altitude Aerial Photography
Vintage 1978 - 1986

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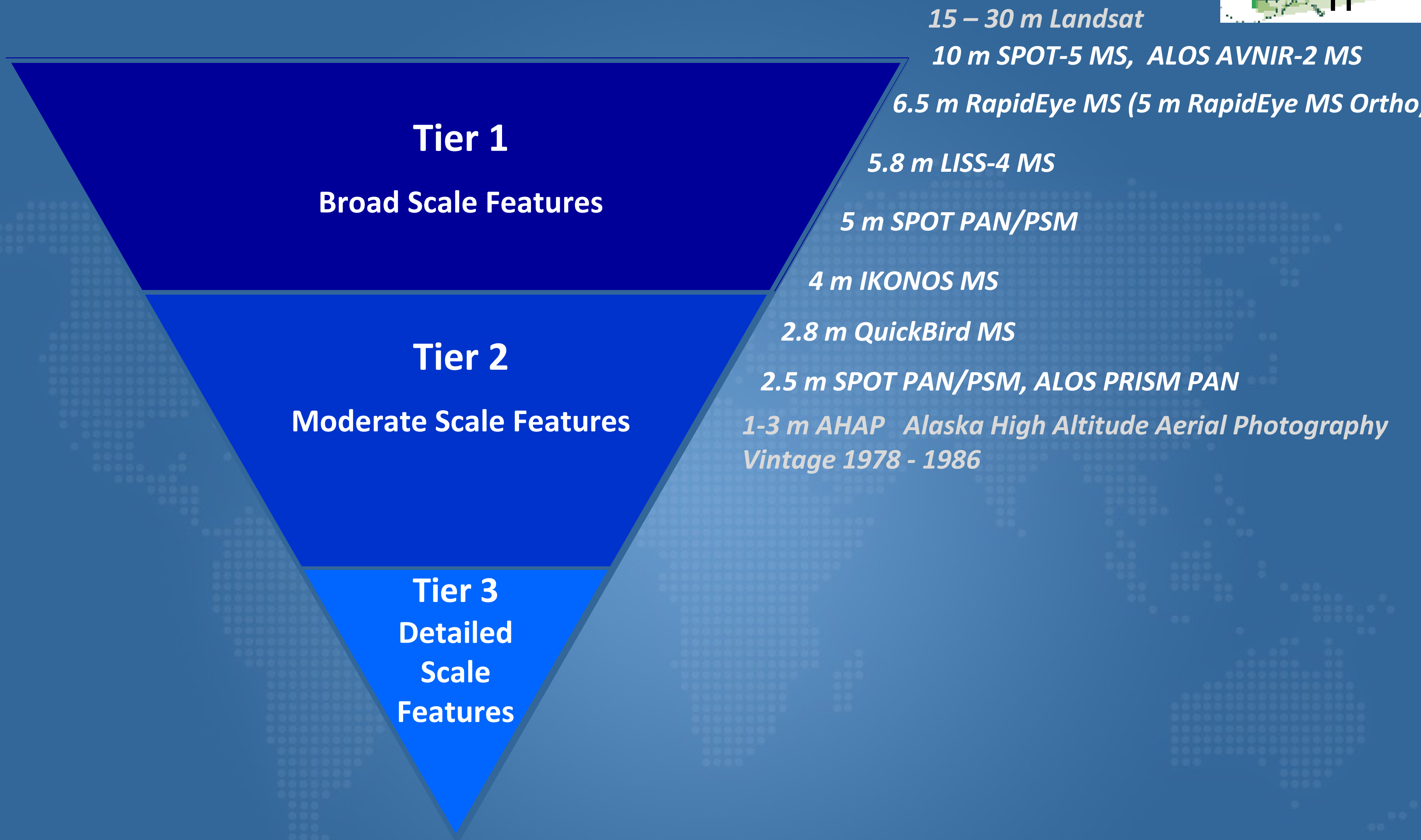

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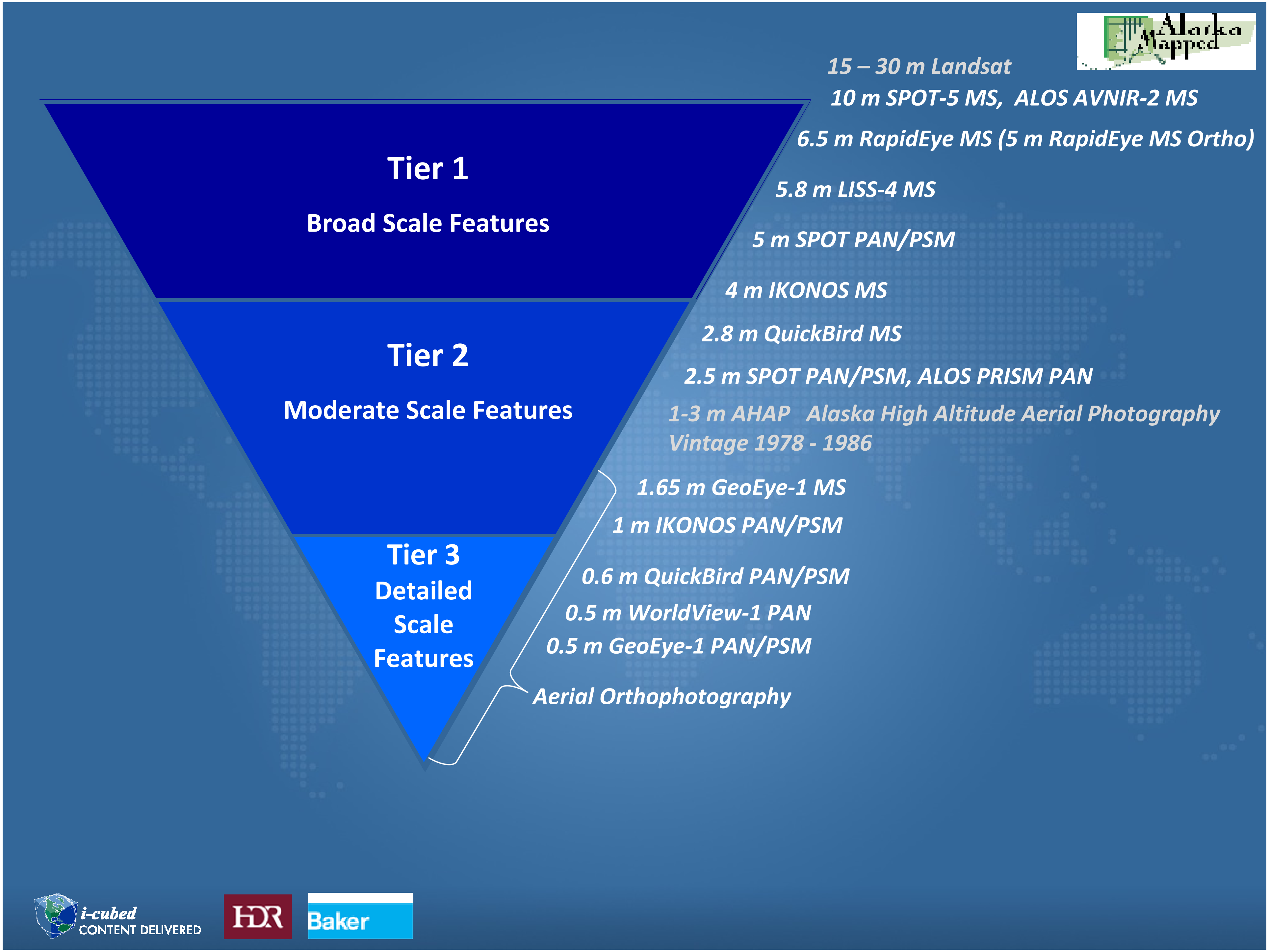
Tier 1
Broad Scale Features
Tier 2
Moderate Scale Features
Tier 3
Detailed Scale Features
15 – 30 m Landsat
10 m SPOT-5 MS, ALOS AVNIR-2 MS
6.5 m RapidEye MS (5 m RapidEye MS Ortho)
5.8 m LISS-4 MS
5 m SPOT PAN/PSM
4 m IKONOS MS
2.8 m QuickBird MS
2.5 m SPOT PAN/PSM, ALOS PRISM PAN
1-3 m AHAP Alaska High Altitude Aerial Photography
Vintage 1978 - 1986
1.65 m GeoEye-1 MS
1 m IKONOS PAN/PSM
0.6 m QuickBird PAN/PSM
0.5 m WorldView-1 PAN
0.5 m GeoEye-1 PAN/PSM
Aerial Orthophotography
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% of respondents requiring color, MS, or CIR imagery is **77%**

Refresh of Imagery every

70% want minimum 5 year refresh of imagery basemap
46% favor 3 year refresh or better

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MAPPING ALASKA

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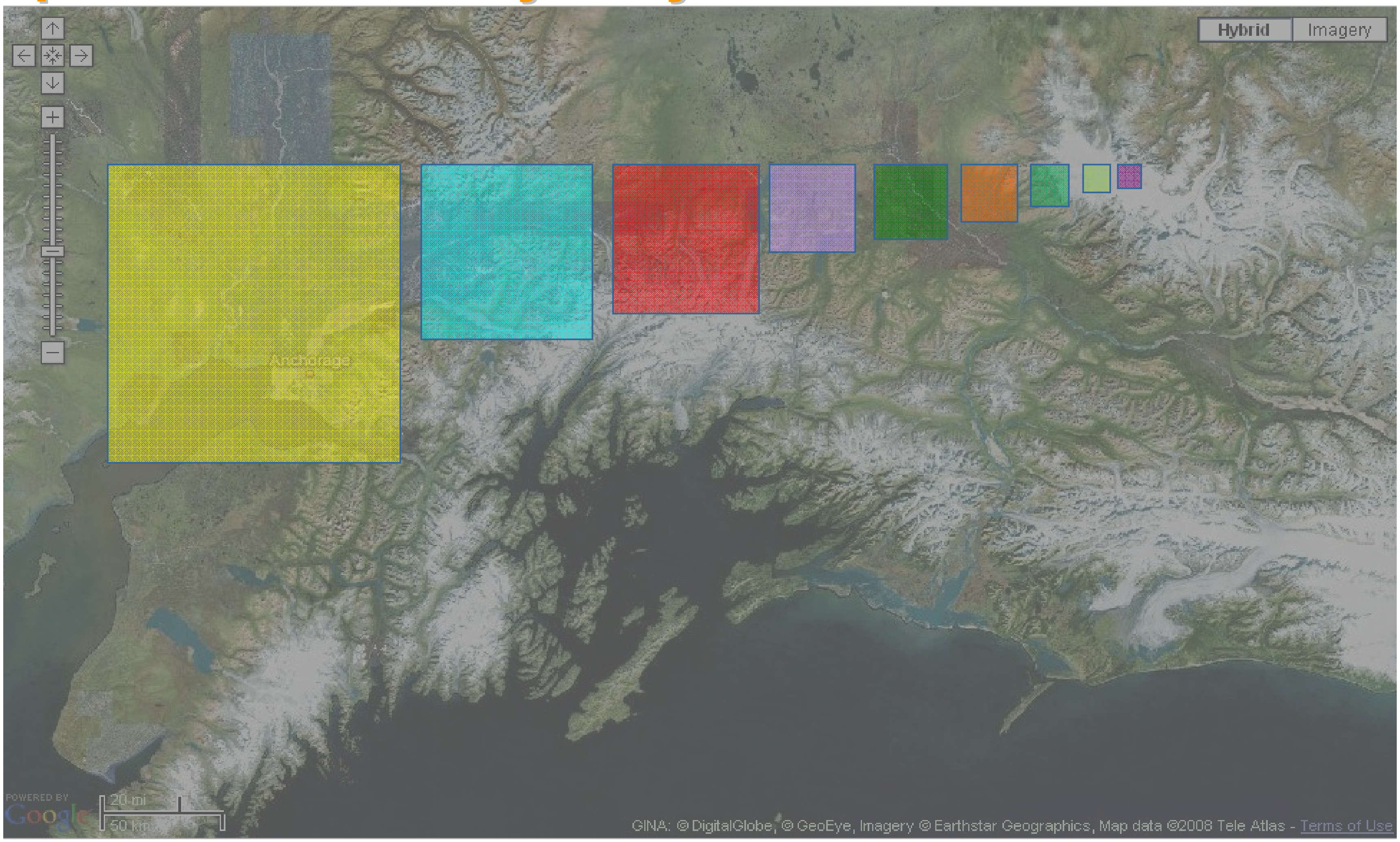
Collection Capacity & Spectral Continuity Vary w/ Sensor



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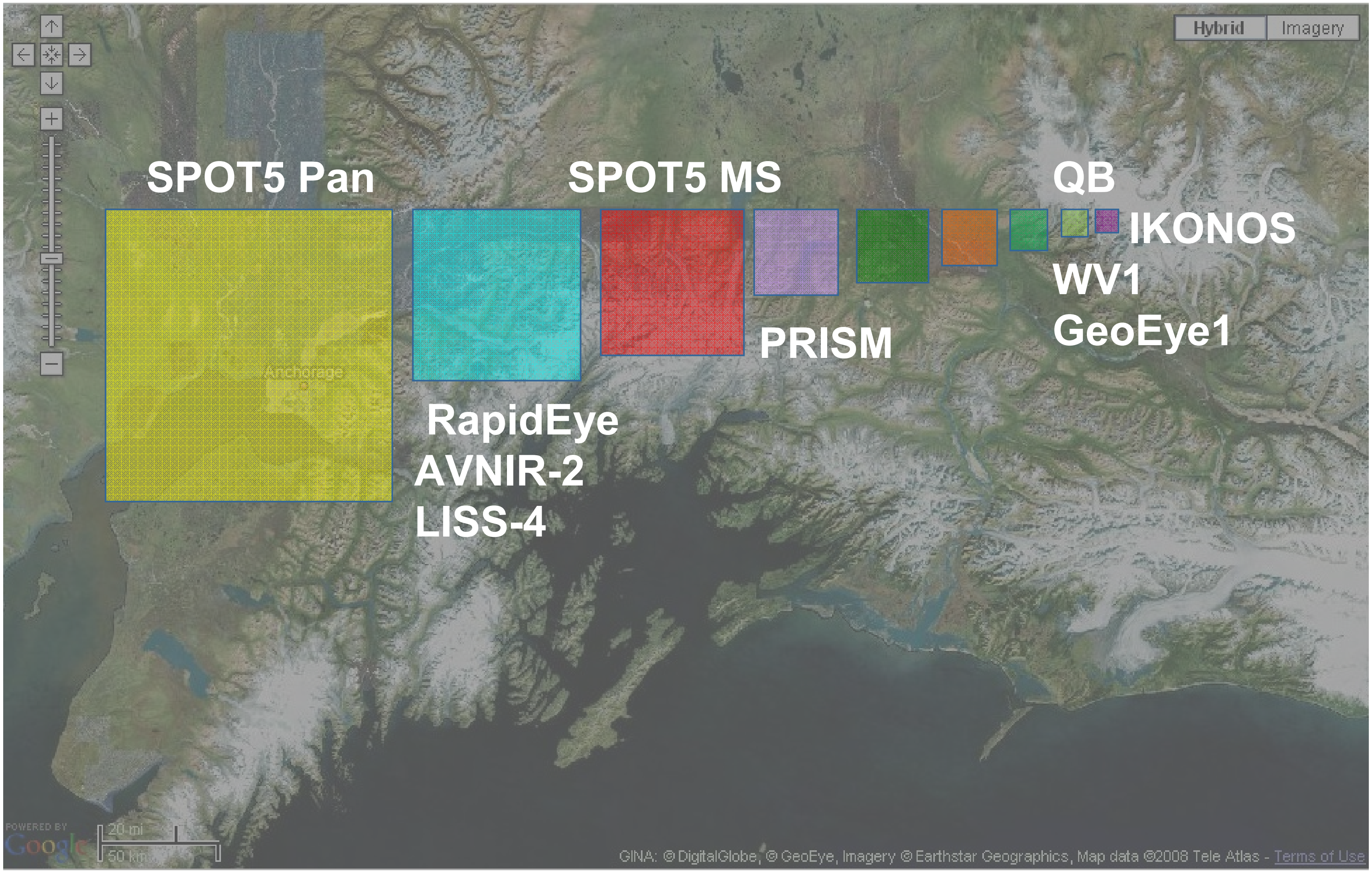
Some Examples



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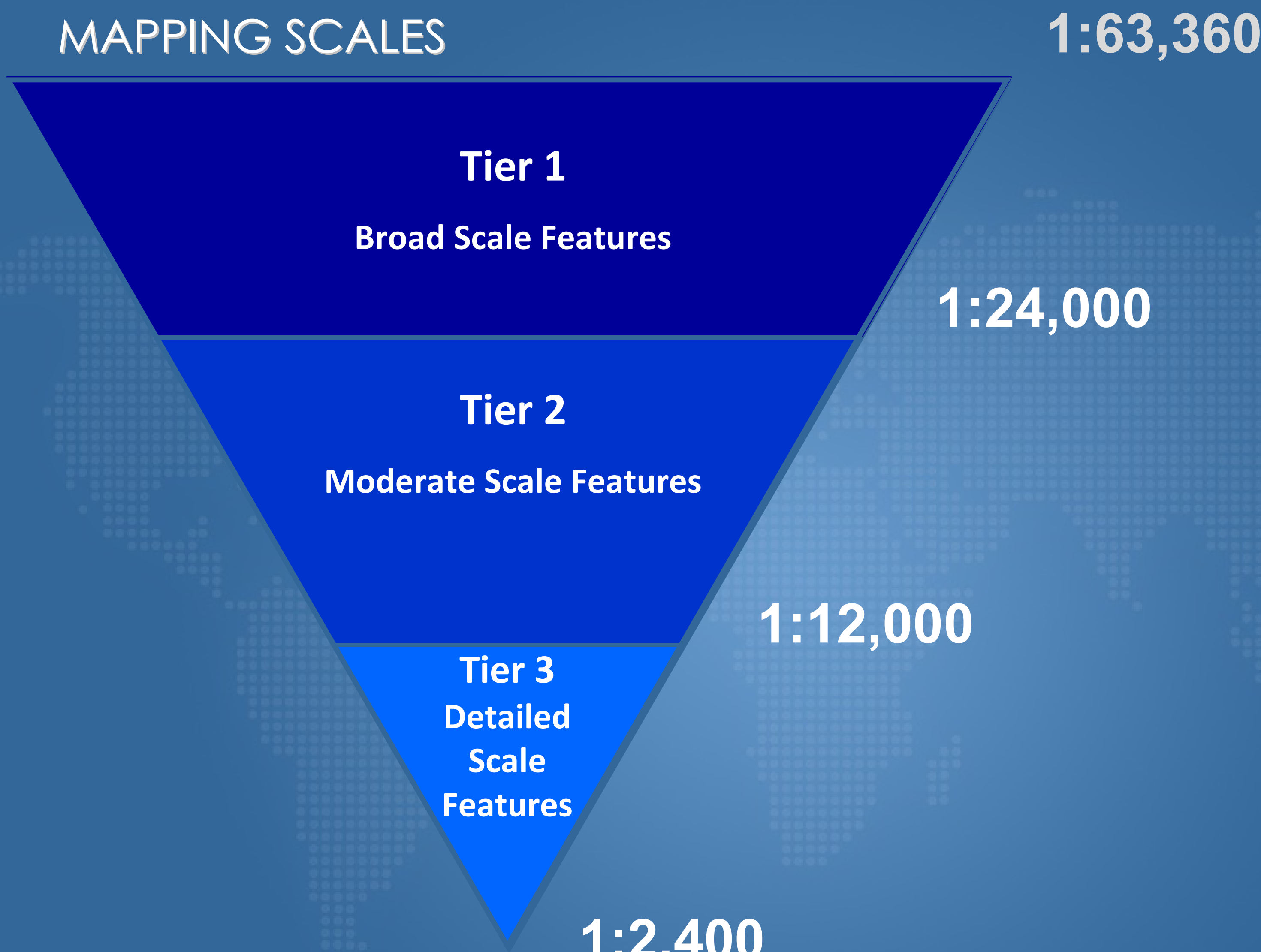
MAPPING SCALES



2 MEANINGS OF MAPPING SCALE

- Accuracy
  - Often to NMAP or CE90 etc.
  - Fairly easy to plan and measure
  - DEM component is often misunderstood caveat for policy makers
- Display
  - Feature identification
  - Correlation with traditional uses of topographic map scales

Scale	Res. (m)
100,000	10.0
50,000	5.0
24,000	2.4
12,000	1.2

ERROR BUDGET

- The term *error budget* (also known as *uncertainty budget*) is used by many industries to mean the partitioning of total error into specific components, in order to evaluate the impact of each on the overall system. Ideally, an error budget is used early in a process to help the designers of a system choose components that minimize or eliminate errors, in order to meet a certain overall accuracy requirement (Mancini).
- In remote sensing, an error budget is used to define and quantify the various sources that contribute to the inaccuracy (also known as circular error) in a given project area. By identifying these specific sources of error, the components that supply the most error or that can be most easily remedied are identified (Congalton).

ERROR BUDGET CALCULATIONS

This worksheet will calculate the expected accuracy of an orthoimage, or a set of orthoimages

Enter information in blue areas.

Results are shown in red areas.

Project information:		
Project Name:	Alaska SDMI	
Location:	Alaska	
Accuracy level (CE/LE %):	90	
What units do you want to use? Enter meters, feet, inches, or centimeters	meters	

Satellite information:		
Name of satellite:	IKONOS	
Source pixel size in meters:	1.00	(m)
Maximum look angle in project area:	24.00	(deg)
Error inherent in satellite model (CE90) with best method (e.g. rigorous) using ground control:	2.000	(m)
Error inherent in satellite model/ephemeris (CE90) with best method (e.g. RPCs) - satellite source dependent:	10.000	(m)

DEM information:		
Description of DEM:	G-DEM	
Vertical error (LE90):	11.58	(m)
Horizontal error (CE90):	0.00	(m)
90th percentile of slope (can extrapolate from DEM):	0.00	(%)

Orthorectification:		
Are you using ground control? Enter Y or N.	y	
If using ground control - follow minimum ground control recommendations at right		
Circular accuracy (CE90) of ground control:	10.900	(m)
Photo-identifiable precision of ground control (use 0.5 pix if good):	1.000	(input pix)

Predicted circular accuracy of orthorectified product:		
Error due to vertical accuracy of DEM:	5.156	(m)
Error due to horizontal accuracy of DEM:	0.000	(m)
Error due to ground control circular error:	10.900	(m)
Error due to ground control photo-identifiability:	1.000	(m)
Error due to satellite model:	2.000	(m)
Predicted circular accuracy (CE90):	**12.263**	**(m)**
CE90/NMAS error	**12.263**	**(m)**
CE95/NSSDA error	**14.613**	**(m)**
NMAS scale	**1: 24,141**	

Horizontal (circular) error conversion		
input level	90	CE % or RMSE
input error	6.50	(m)
output level	90	CE %
output error	6.50	(m)

Vertical error conversion		
input level	68	LE % or RMSE
input error	7.00	(m)
output level	90	LE %
output error	11.58	(m)

Minimum ground control recommendations	
QuickBird	10x10 km
IKONOS	10x50 km, min. 2 per strip
SPOT	10 points per scene
Others	check with vendor

Supporting Documentation

SATELLITE ORTHO ACCURACY ESTIMATION WORKSHEET

YUSUF SIDDIQUI, RESEARC
I-CUBED : INFORMATION I

INTRODUCTION

The term *error budget* (also known
total error into specific component
error budget is used early in a proc
eliminate errors, in order to meet a

In remote sensing, an error budget
inaccuracy (also known as circular
components that supply the most e
Satellite Ortho Accuracy Estimation
components of an error budget for
each field of the spreadsheet, follo
calculations.

Note that the words *accuracy* and

GENERAL SPREADSHEET TIP

The user should enter information
will not be able to overwrite them.
section or another, the instruction

PROJECT INFORMATION SE

This is where basic information abo
form text fields. The accuracy leve
63.21%, 90% or 95%. If evaluating
evaluating for NSSDA, 95% should b
error. The last field in this section
asked for or reported.

APPENDIX 1 – SATELLITE ANGLE RELATIONSHIPS

Figure 4 shows the triangular relationship between the satellite, the ellipsoid, and the approximate center of the earth. The angle subtended at the center of the earth is the angular difference between the incidence angle and the look angle, due to the fact that the three angles of the triangle must add up to 180°:

$$\theta_l + \theta_s + (180° - \theta_i) = 180° \quad \text{(Eq. 13)}$$

$$\theta_i = \theta_l + \theta_s \quad \text{(Eq. 14)}$$

where θ_l = look angle
θ_s = angle subtended
θ_i = incidence angle

The Law of Sines can be used to calculate the third angle of the triangle in Figure 4, which in turn can be used to calculate the incidence angle (using the trigonometric identity sin θ = sin(180° - θ)):

$$\frac{r_s + h_s}{\sin\theta_i} = \frac{r_g}{\sin\theta_l} \quad \text{(Eq. 15)}$$

$$\theta_i = \sin^{-1}\left(\sin\theta_l \frac{r_s + h_s}{r_g}\right) \quad \text{(Eq. 16)}$$

where r_s = earth radius at satellite
h_s = height above ellipsoid of satellite
r_g = earth radius at ground

Given an ellipsoid, a latitude, and a longitude, the ellipsoidal radius of the earth at any given point can be calculated. Since we do not necessarily know where the satellite or scene center will be, the earth can be approximated as a sphere to get around the need to have a location. The mean earth radius of 6371 km is used in the spreadsheet. Substituting this in to Equation 16 gives:

$$\theta_i = \sin^{-1}\left(\sin\theta_l \frac{r_m + h_s}{r_m}\right) \quad \text{(Eq.}$$

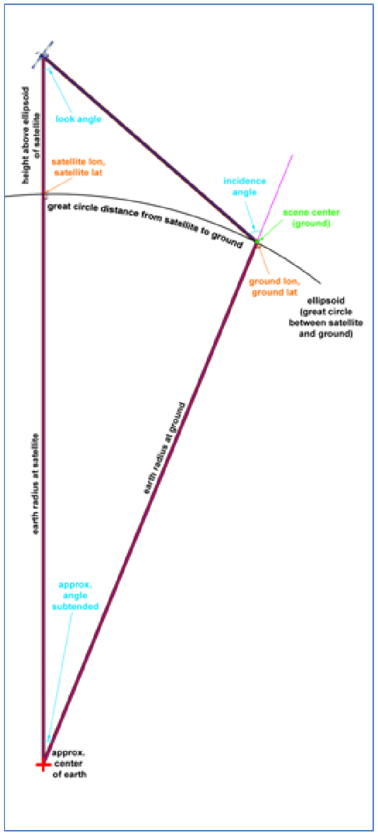


Figure 4

APPROXIMATE MAP SCALE EQUIVALENCIES

Map Scale	CE90	RMSE	1-Sigma
1:50,000	25.4m	15m	12m
1:24,000	12.2m	6m	3m
1:12,000	10.2m	5m	2m
1:4,800	4.1m	2m	2m
1:2,400	2.0m	1m	1m

ROOT SUM SQUARE

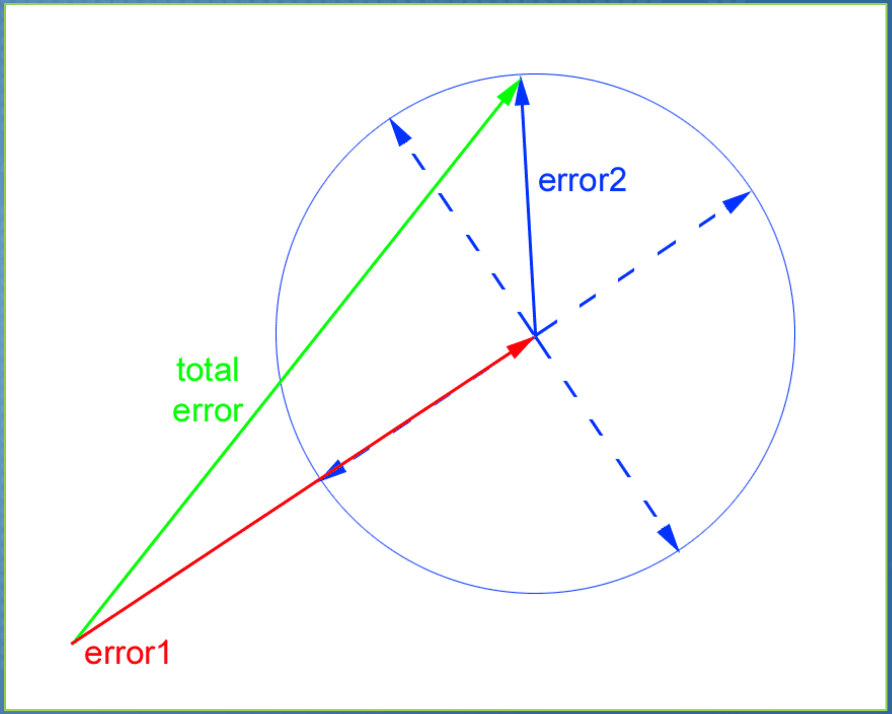
- Overall error is not a linear additive function of the errors but rather the square root of the sum of the squares of the errors because there is some natural cancellation if one assumes the errors are random.

$$\varepsilon_p = \sqrt{\sum \varepsilon_i^2}$$

Predicted circular accuracy of orthorectified product:			
Error due to vertical accuracy of DEM:	5.156	(m)	
Error due to horizontal accuracy of DEM:	0.000	(m)	
Error due to ground control circular error:	1.000	(m)	
Error due to ground control photo-identifiabili	1.000	(m)	rss / linear
Error due to satellite model:	2.000	(m)	
Predicted circular accuracy (CE95):	**5.708**	**(m)**	**9.156**
CE90/NMAS error	**4.790**	**(m)**	
CE95/NSSDA error	**5.708**	**(m)**	
NMAS scale 1:	**6,742**		

RSS ANOTHER VIEW - 1

- Another way of visualizing why circular errors add up this way is to imagine a vector representing the first source of error. In the figure, this is the red arrow. Next, imagine another vector that starts at the tip of this first error, representing a second source of error; this is the blue arrow.
- If the second vector has exactly the same direction as the first, they add up. If it has the opposite direction, they subtract. If it is perpendicular, they add up by the Pythagorean Theorem, which is the same as a root sum square. If anywhere else, the vectors add up by the Law of Cosines; the green arrow represents the summation for the case of an arbitrary direction for the second error.



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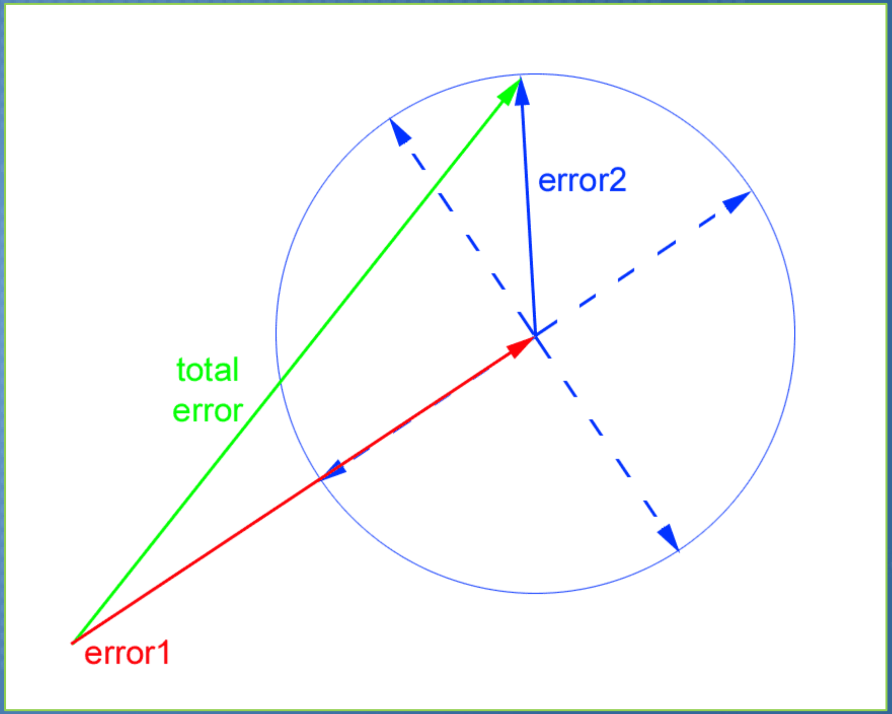
RSS ANOTHER VIEW - 2

- If all directions of the second vector are equally likely (which they should be, given the assumptions of circularity and independence), then the weighted average of all possible directions will be the perpendicular case, which adds with the first as a root sum square. This analogy can be extended to any number of independent error vectors.

- It is useful to note with the sum of squares that the largest error tends to dominate the result. For example, if the error due to the vertical inaccuracy of the DEM is 10 meters and the only other error is 5 meters, the result is , or 11.18 meters, which is only 11.8% larger than the largest error.



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ERROR BUDGET CALCULATIONS

This worksheet will calculate the expected accuracy of an orthoimage, or a set of orthoimages

Enter information in blue areas.

Results are shown in red areas

Project Information:		
Project Name:	Alaska SDMI	
Location:	Alaska	
Accuracy level (CL/LL %):	90	
What units do you want to use? Enter meters, feet, inches, or centimeters	meters	

Satellite information:		
Name of satellite	IKONOS	
Source pixel size in meters:	1.00	(m)
Maximum look angle in project area	24.00	(deg)
Error inherent in satellite model (CE90) with best method (e.g. rigorous) using ground control:	2.000	(m)
Error inherent in satellite model/ephemeris (CL90) with best method (e.g. RPCs) - satellite source dependent:	10.000	(m)

DEM information:		
Description of DEM:	G DEM	
Vertical error (LE90)	11.58	(m)
Horizontal error (CL90):	0.00	(m)
90th percentile of slope (can extrapolate from DEM):	0.00	(%)

Orthorectification:		
Are you using ground control? Enter Y or N	y	
If using ground control - follow minimum ground control recommendations at right		
Circular accuracy (CL90) of ground control:	10.900	(m)
Photo identifiable precision of ground control (use 0.5 pix if good):	1.000	(input pix)

Predicted circular accuracy of orthorectified product:		
Error due to vertical accuracy of DEM:	5.156	(m)
Error due to horizontal accuracy of DEM	0.000	(m)
Error due to ground control circular error:	10.900	(m)
Error due to ground control photo-identifiability	1.000	(m)
Error due to satellite model:	2.000	(m)
Predicted circular accuracy (CE90):	12.263	(m)
CL90/NMAS error	12.263	(m)
CE95/NSSDA error	14.613	(m)
NMAS scale	1: 24,141	

Horizontal (circular) error conversion		
input level	90	CL % or RMSL
input error	6.10	(m)
output level	90	CL %
output error	6.10	(m)

Vertical error conversion		
input level	68	LL % or RMSL
input error	7.00	(m)
output level	90	LL %
output error	11.58	(m)

Minimum ground control recommendations	
QuickBird	10x10 km
IKONOS	10x50 km, min. 2 per strip
SPOT	10 points per scene
Other	check with vendor

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ERROR BUDGET SPREADSHEET

- If evaluating for National Map Accuracy standards, 90% should be used, whereas if evaluating for NSSDA, 95% should be used. Use 63.21% for an RMSE or 1-sigma standard, or 50% for the average error.

Project information:	
Project Name:	**Alaska SDMI**
Location:	Alaska
Accuracy level (CE/LE %):	95
What units do you want to use? Enter mete	meters

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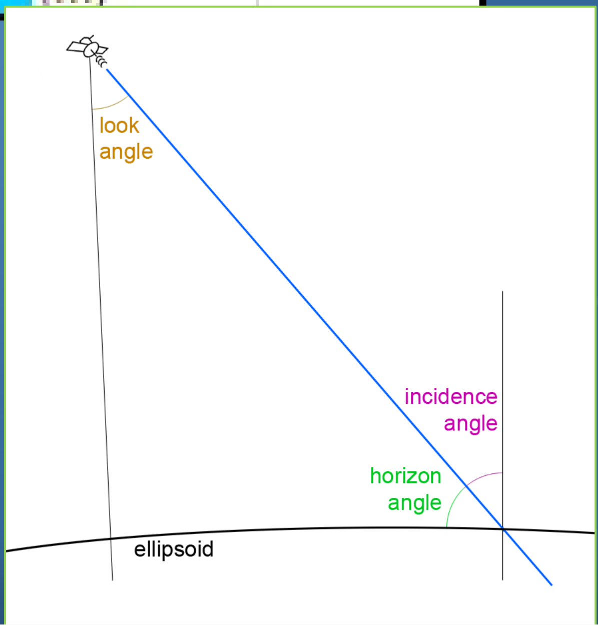
ERROR BUDGET SPREADSHEET

- The third field (F22) represents the maximum expected incidence angle from the satellite to the ground. If the spreadsheet is to be used for an error budget for a single image of known incidence angle, enter that here.

Satellite information:		
Name of satellite:	IKONOS	
Source pixel size in meters:	1.00	(m)
Maximum incidence angle in project area:	24.00	(deg)
Error inherent in satellite model (CE95) with be	2.000	(m)
Error inherent in satellite model/ephemeris (	10.000	(m)



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ERROR BUDGET SPREADSHEET

- The fourth field (F23) may be the most difficult to determine. This is the error inherent in the satellite model using the best orthorectification model. For example, a typical algorithm used in orthorectification software is the “rigorous” model, which takes into account the physical characteristics of the sensor. The error reported in this field represents the uncertainty in the model of satellite position, attitude, and camera model, even if the DEM and ground control are perfect.

Satellite information:		
Name of satellite:	IKONOS	
Source pixel size in meters:	1.00	(m)
Maximum incidence angle in project area:	24.00	(deg)
Error inherent in satellite model (CE95) with be	2.000	(m)
Error inherent in satellite model/ephemeris (	10.000	(m)

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ERROR BUDGET SPREADSHEET

- Cell F24 is used to report the error inherent in the satellite model using the best method available when ground control is *not* used. Typically, this would be a model that uses rational polynomial coefficients, or RPCs. Most vendors provide RPCs with their non-orthorectified ("basic") imagery, and they often will quote a number that represents the accuracy you can expect using RPCs without ground control.

Satellite information:						
Name of satellite:			IKONOS			
Source pixel size in meters:				1.00	(m)	
Maximum incidence angle in project area:				24.00	(deg)	
Error inherent in satellite model (CE95) with be				2.000	(m)	
Error inherent in satellite model/ephemeris (				10.000	(m)	

ERROR BUDGET SPREADSHEET

- The vertical error field (F36) should contain the quoted vertical error of the DEM, also known as LE (linear error) at a certain value. The percentile used is the same as what is defined in cell F15.
- If you are given a different value from the percentile that is asked for, use the vertical error conversion form at the right to perform this conversion. Type in the word "RMSE" if you know the RMSE (root mean square error) of the data, otherwise type in a percentage value, such as "90" or "95" in cell K19. Next, type the value of given number in cell K20 (example: CE90 of 4.5 meters means "90" goes into K19 and "4.5" goes into K20). The calculated vertical error at the given level (the same level used for the entire sheet) is given in cell K22.

DEM information:		
Description of DEM:	G-DEM	
Vertical error (LE95):	11.58	(m)
Horizontal error (CE95):	0.[illegible]	(m)
95th percentile of slope (can extrapolate fror	0.[illegible]	

Vertical error conversion		
input level	90	LE % or RMSI
input error	1000.00	(m)
output leve	95	LE %
output erro	1191.57	(m)

ERROR BUDGET SPREADSHEET

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- The last field in this section (F38) is the X^{th} percentile of slope over the project area, where X is the accuracy level defined in cell F15. Note that this field is only relevant if the horizontal error in cell F37 is non-zero. To determine this value, it may be necessary to build a DEM for the project area, perform a slope analysis, and determine the X^{th} percentile by analyzing the histogram. Use the best freely-available DEM, as coarse datasets like SRTM30 will tend to underestimate the slope values in a much higher resolution elevation model.

DEM information:		
Description of DEM:	G-DEM	
Vertical error (LE95):	11.58	(m)
Horizontal error (CE95):	0.00	(m)
95th percentile of slope (can extrapolate fror	0.00	(%)

ERROR BUDGET SPREADSHEET

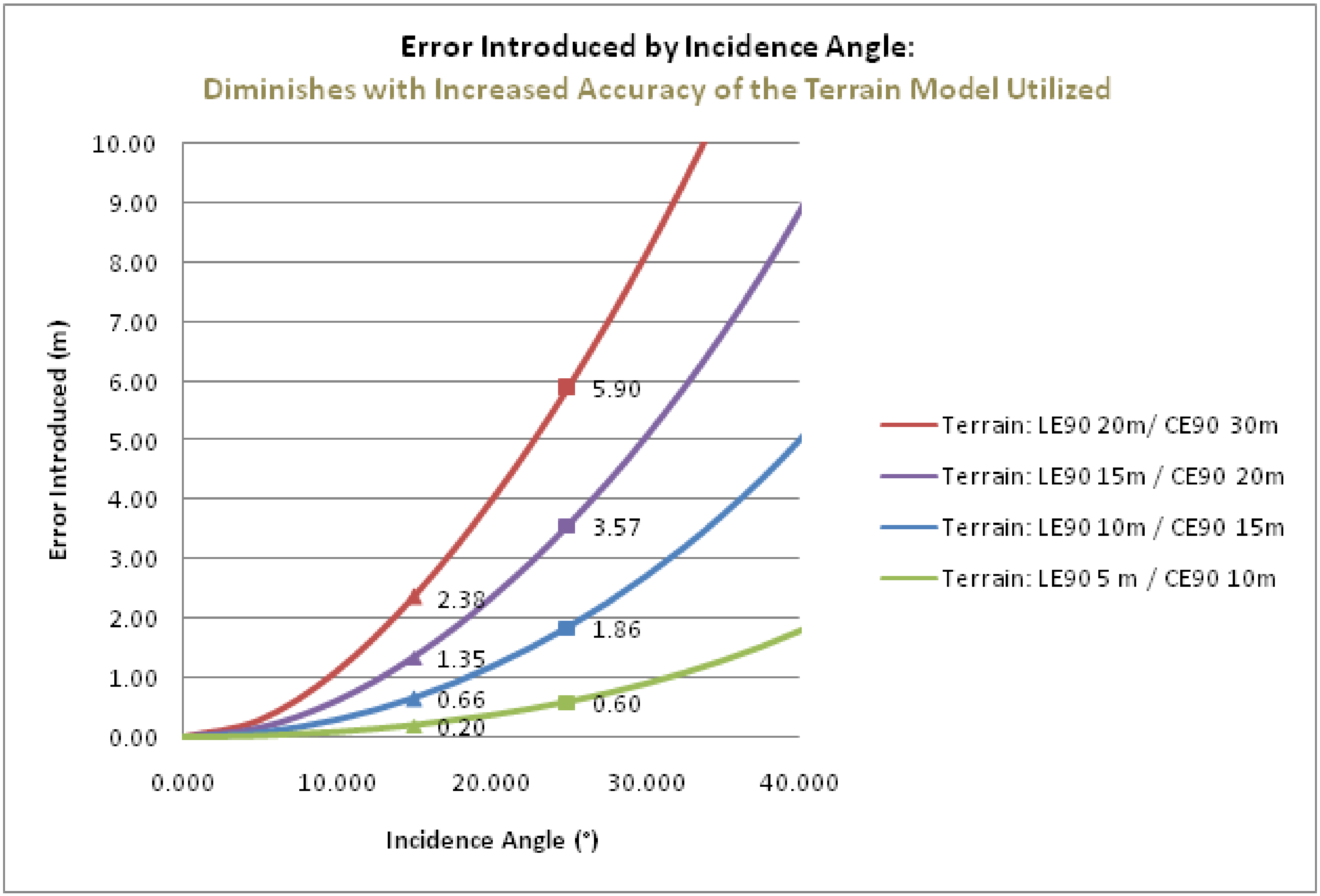
- If GCPs are used, enter the circular accuracy of the ground control at the X^{th} percentile in the first field (F45), where X is the accuracy level defined in cell F15. This number should be provided by the ground control supplier. If survey points are the primary source of control, the quoted accuracy of those points should be entered here. If high-resolution imagery is to be used, enter the circular accuracy of this imagery in this field.

Orthorectification:			
Are you using ground control? Enter Y or N		y	
If using ground control - follow minimum ground control recommendations at right			
	Circular accuracy (CE95) of grou	1.000	(m)
	Photo-identifiable precision of grc	1.000	(input pix)

ERROR BUDGET SPREADSHEET

Predicted circular accuracy of orthorectified product:			
Error due to vertical accuracy of DEM:		5.156	(m)
Error due to horizontal accuracy of DEM:		0.000	(m)
Error due to ground control circular error:		1.000	(m)
Error due to ground control photo-identifiabili		1.000	(m)
Error due to satellite model:		2.000	(m)
Predicted circular accuracy (CE95):		**5.708**	**(m)**
CE90/NMAS error		**4.790**	**(m)**
CE95/NSSDA error		**5.708**	**(m)**
NMAS scale	**1:**	**6,742**	

ERROR INTRODUCED BY INCIDENCE ANGLE



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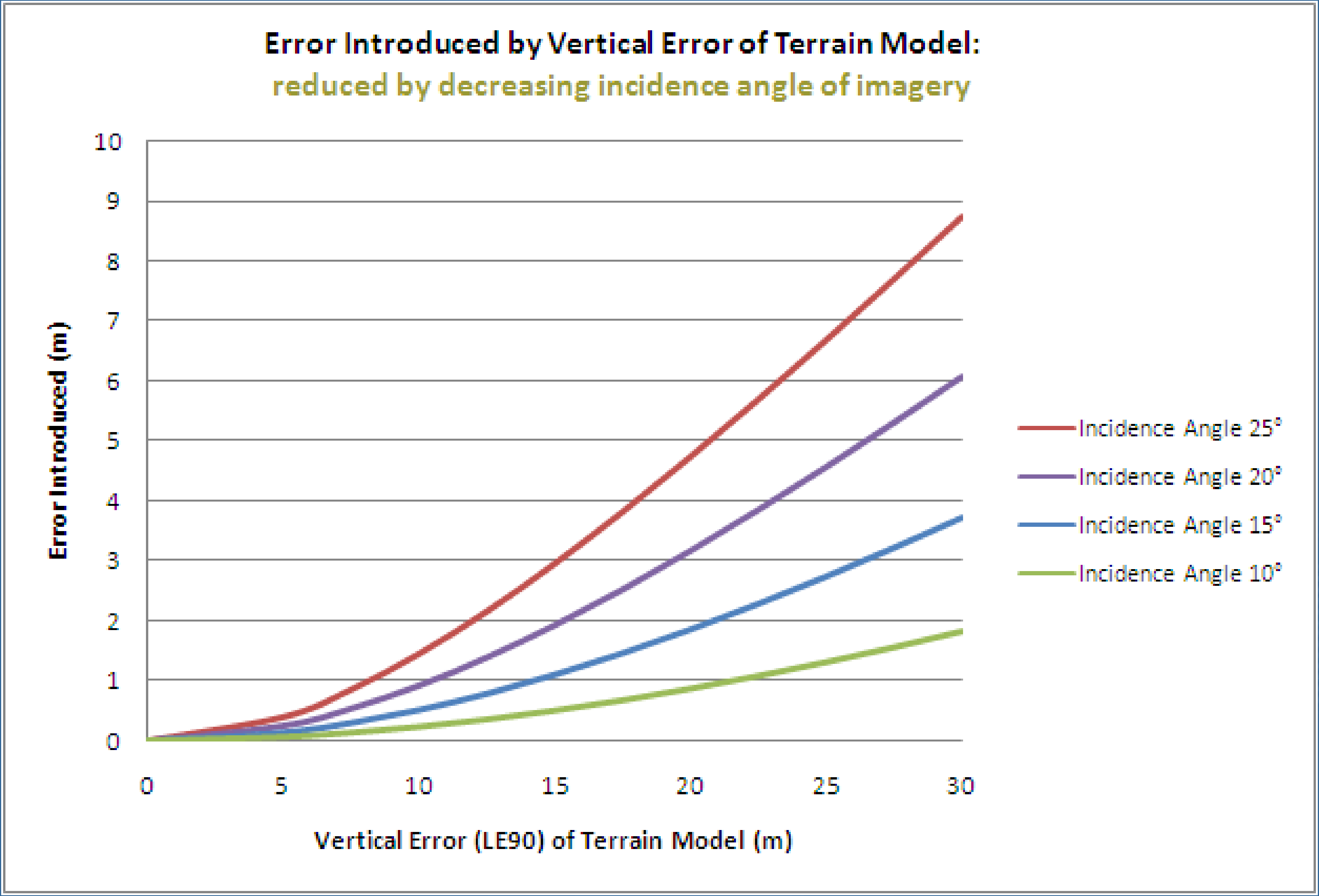
RESTRICT INCIDENCE ANGLE OF IMAGE ACQUISITON



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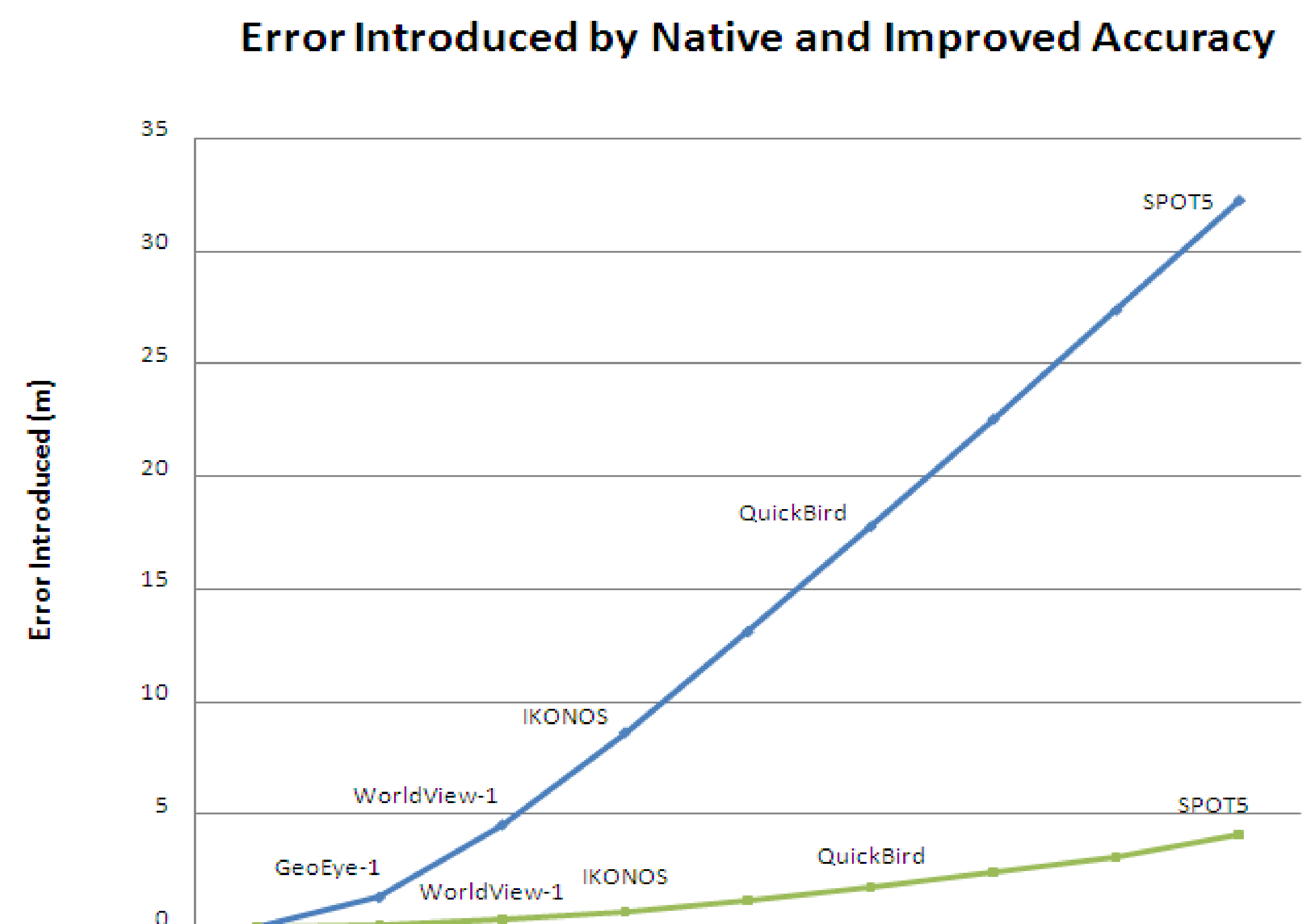
IMPROVEMENT WITH GROUND CONTROL



Native Accuracy (m)	0	1.336	4.557	8.644	13.114	17.775	22.54	27.37	32.24
Improved Accuracy (m)	0	0.0993	0.373	0.703	1.181	1.758	2.417	3.145	4.116

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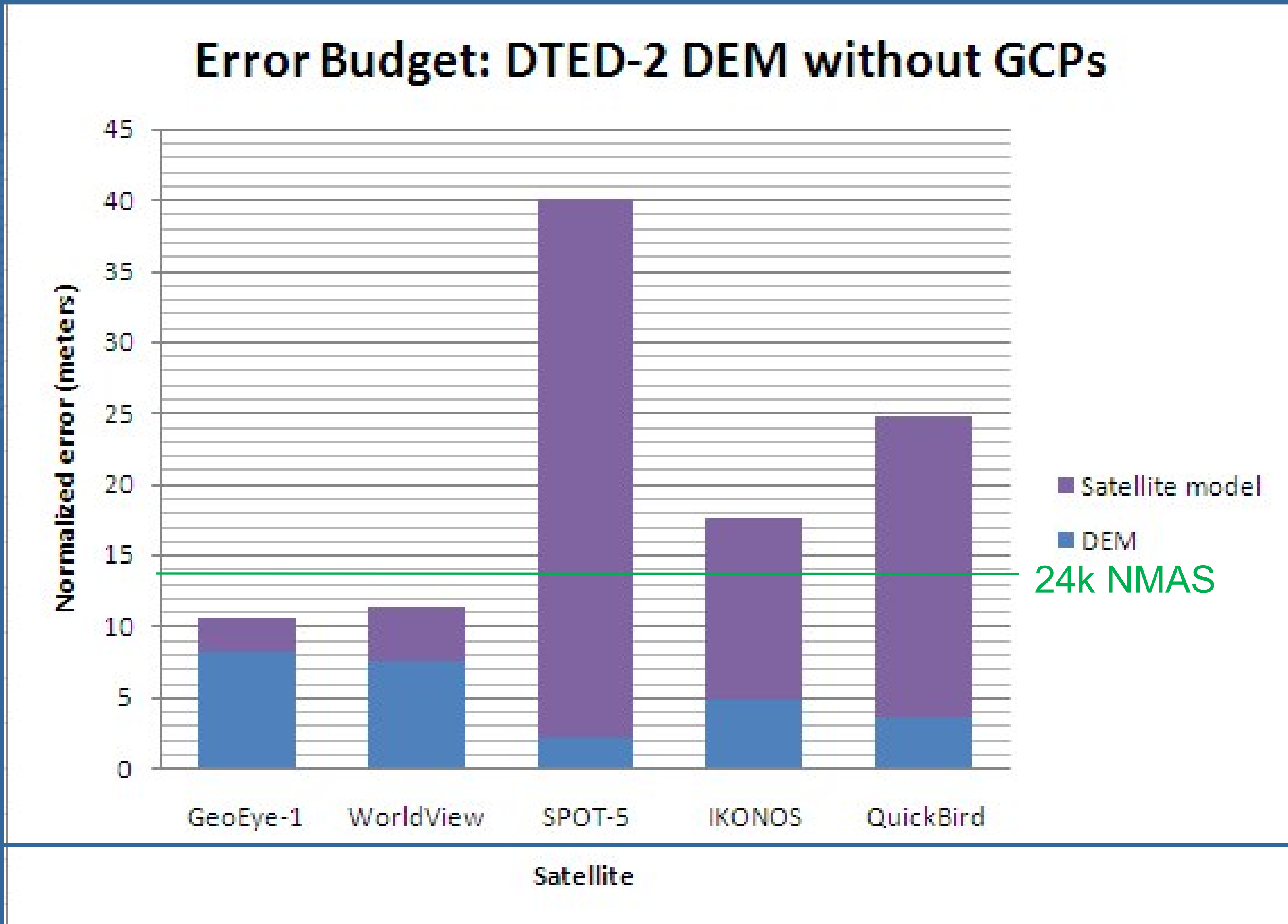
ERROR BUDGET SPREADSHEET



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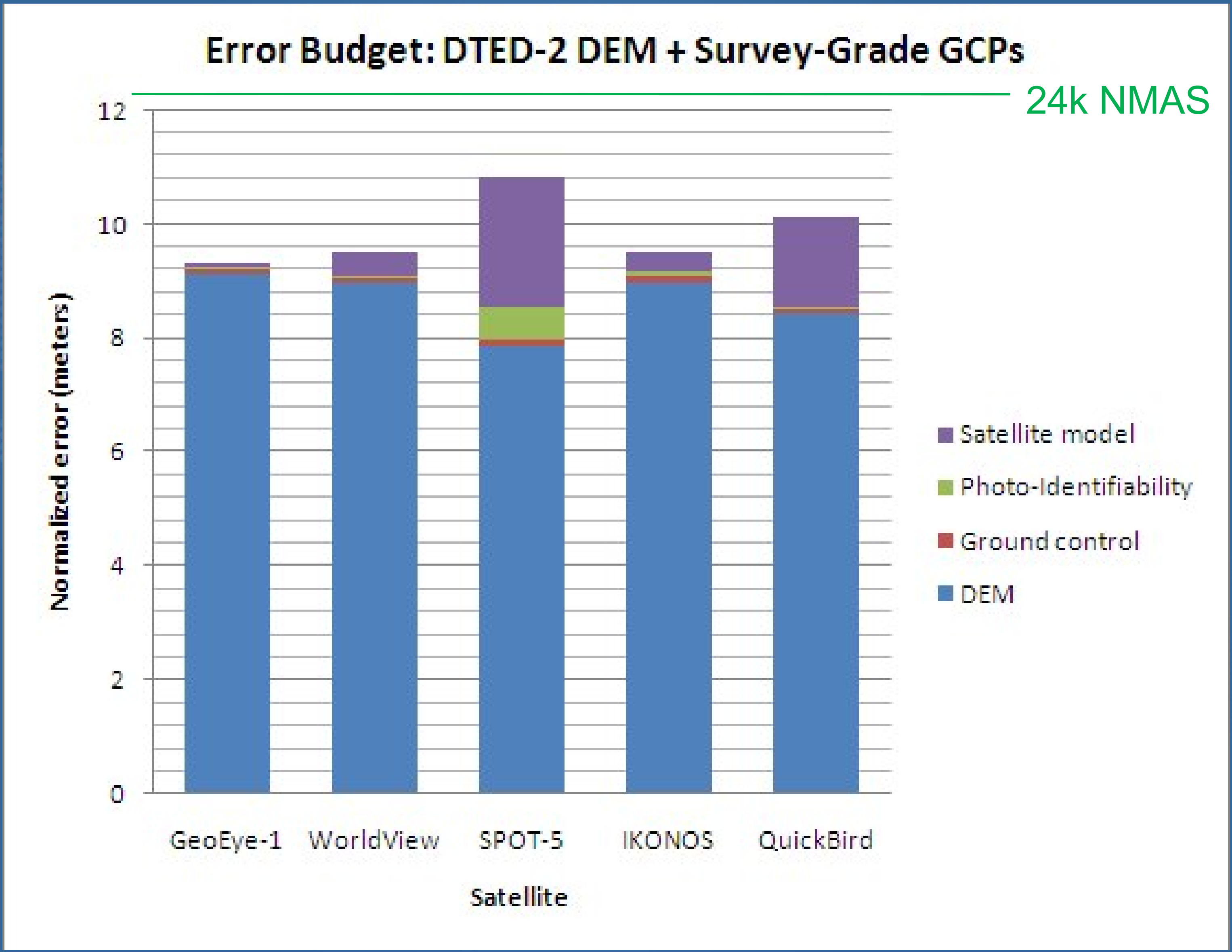
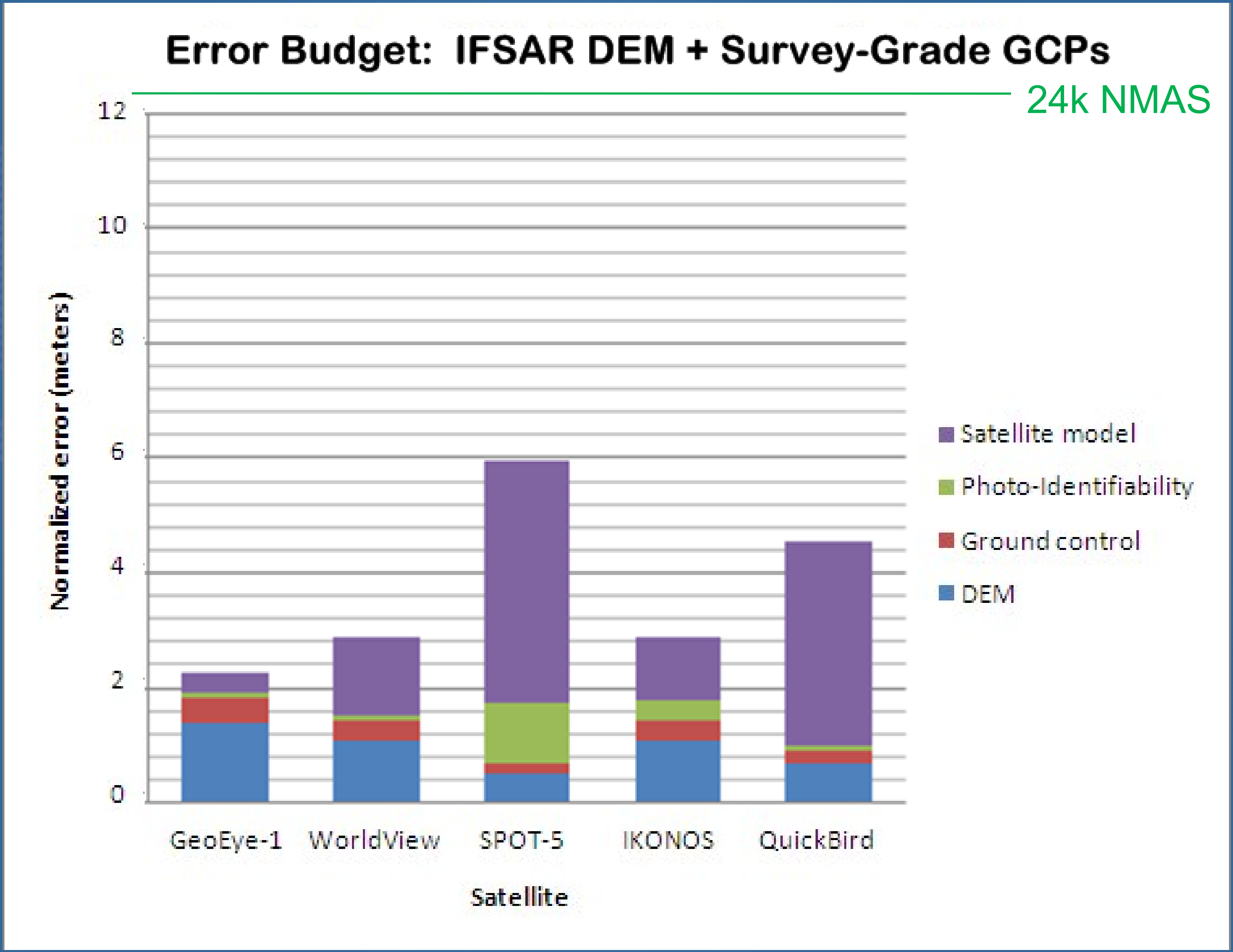


ERROR BUDGET SPREADSHEET



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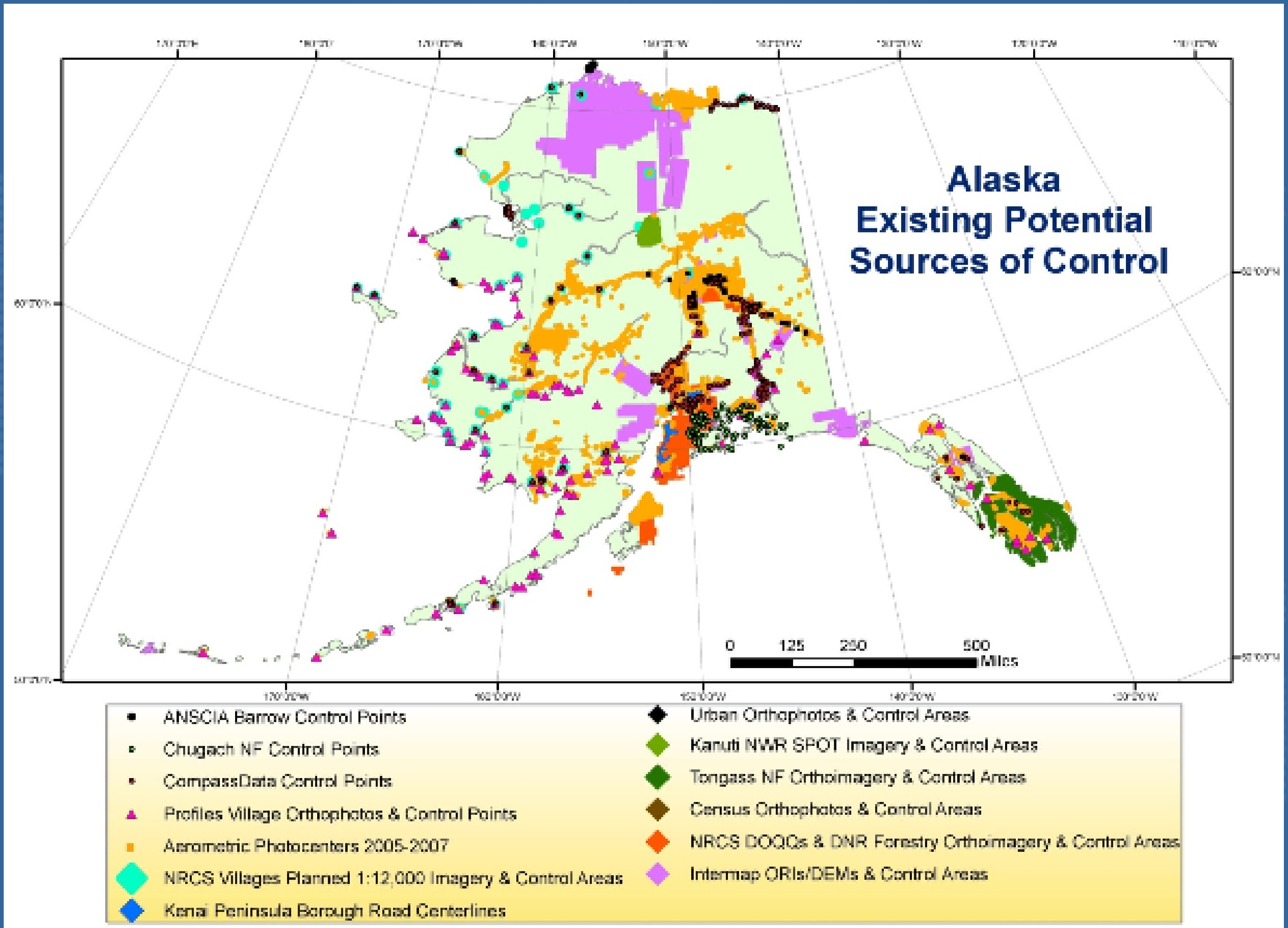

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Agency/Organization	Imagery Area Requirements by Scale/Resolution					
	Broad (2.5-10 meter)		Moderate (1-2.5 meter)		Detailed (sub- to 1-meter)	
	Area (sq. km.)	% of State	Area (sq. km.)	% of State	Area (sq. km.)	% of State
Federal Aviation Administration, ADOT Aviation	1,493,266	100	-	-	155,245	12
US Department of Defense	-	-	8,498	1	234,523	16
National Wetlands Inventory (USFWS)	1,493,266	100	-	-	-	-
USFWS	1,493,266	100	290,343	19	-	-
Bureau of Land Management	1,493,266	100	209,758	14	33,936	2
National Park Service	203,342	14	203,342	14	-	-
USDA Forest Service	1,493,266	100	-	-	85,942	6
State of Alaska (including ADOT), Alaska Railroad Corp.	1,493,266	100	413,180	28	305,912	20
Native Corpsorations & Organizations	1,493,266	100	-	-	174,650	12
Boroughs, Municipalities, Cities	-	-	528,234	35	104,990	7
Populated Places (Municipalities, Cities, Villages) - Buffered 10 km	-	-	-	-	229,299	15
Major Roads & Railroads - Buffered 5 km	-	-	-	-	58,020	4
Trans-Alaska Pipeline & Other Pipelines - Buffered 10 km	-	-	-	-	25,223	2
Utilities & Infrastructure	-	-	-	-	55,541	4
NON-OVERLAPPING AREA TOTALS	1,493,266	**100**	1,205,591	**81**	409,062	**27**

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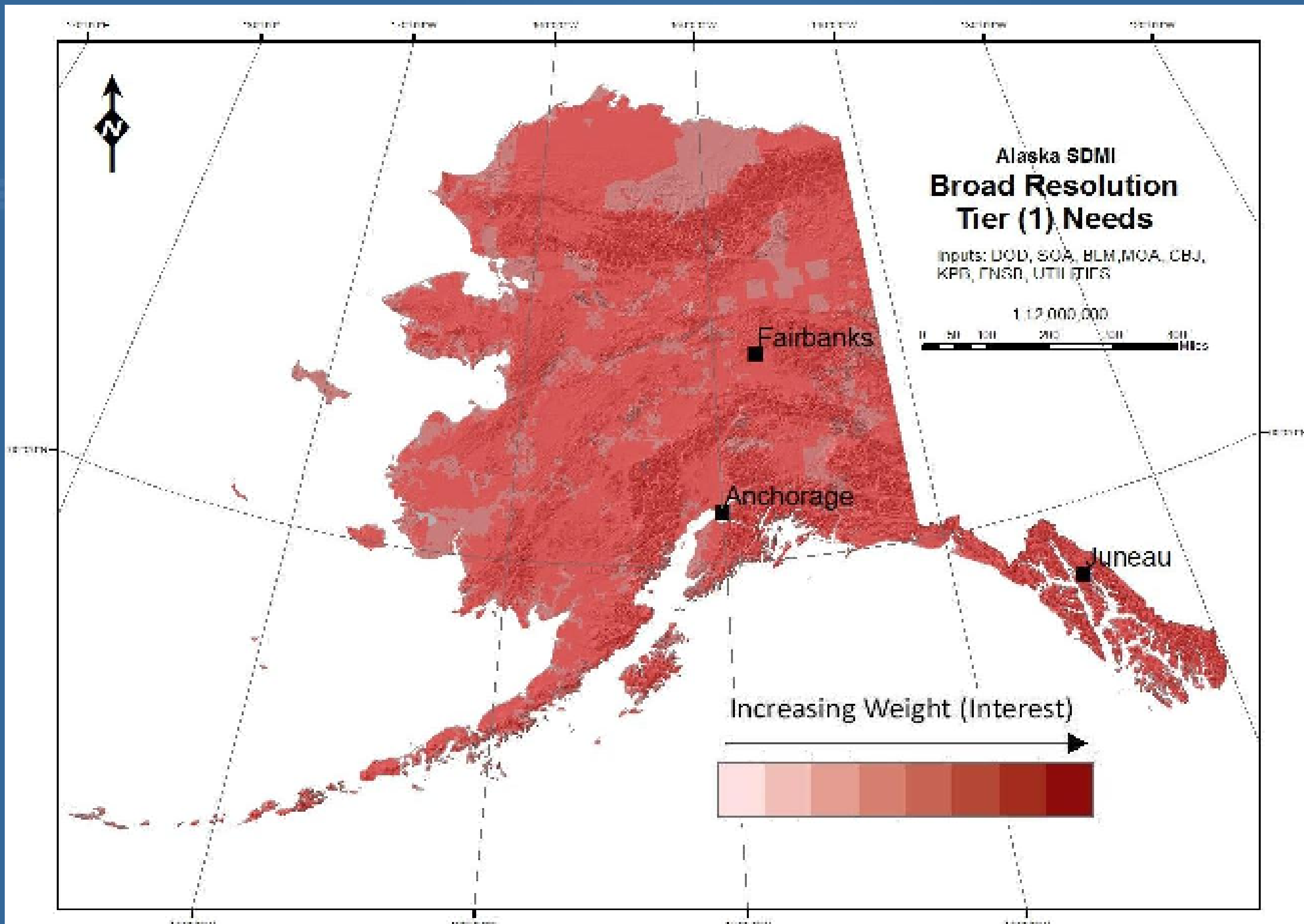

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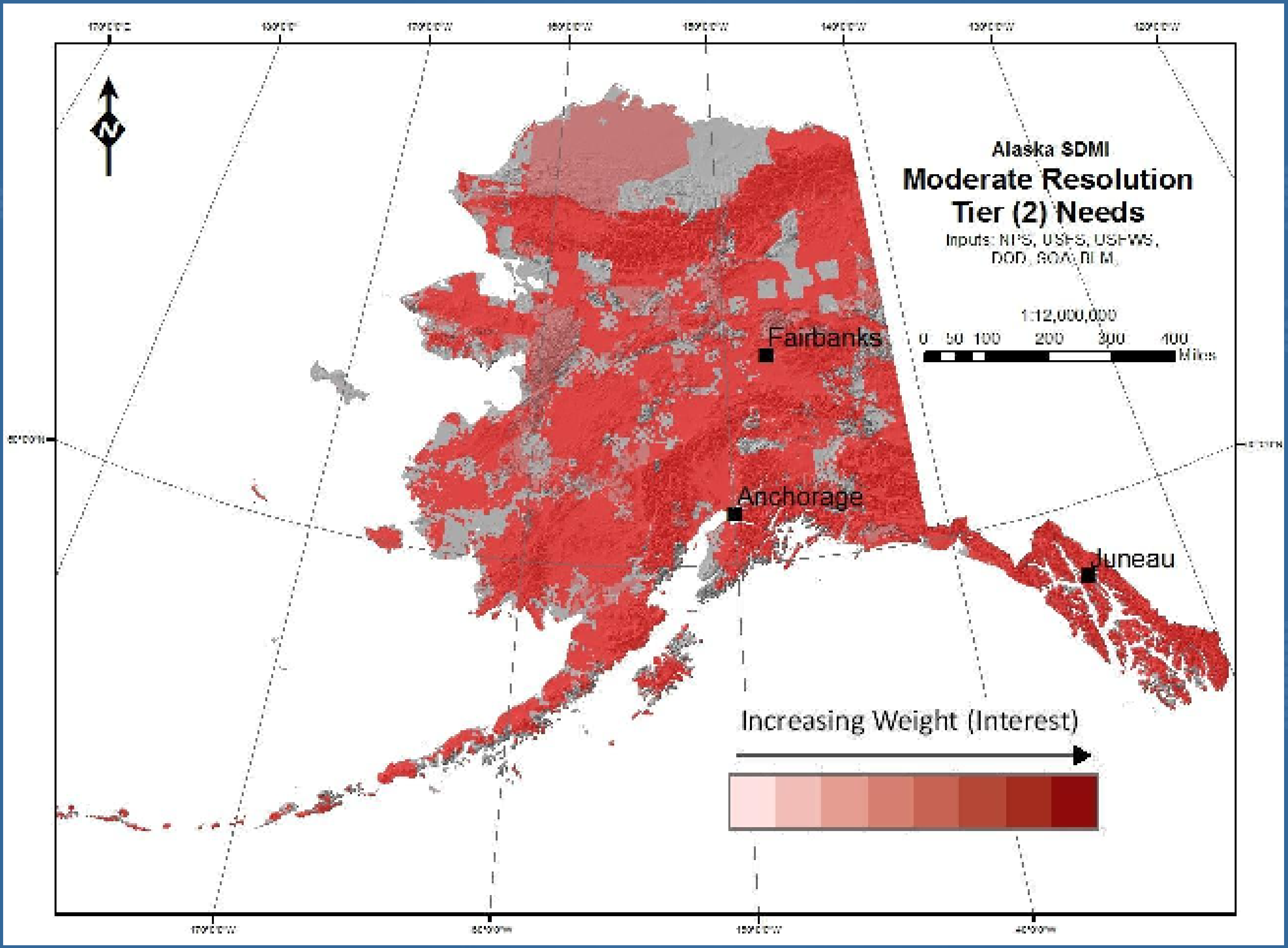

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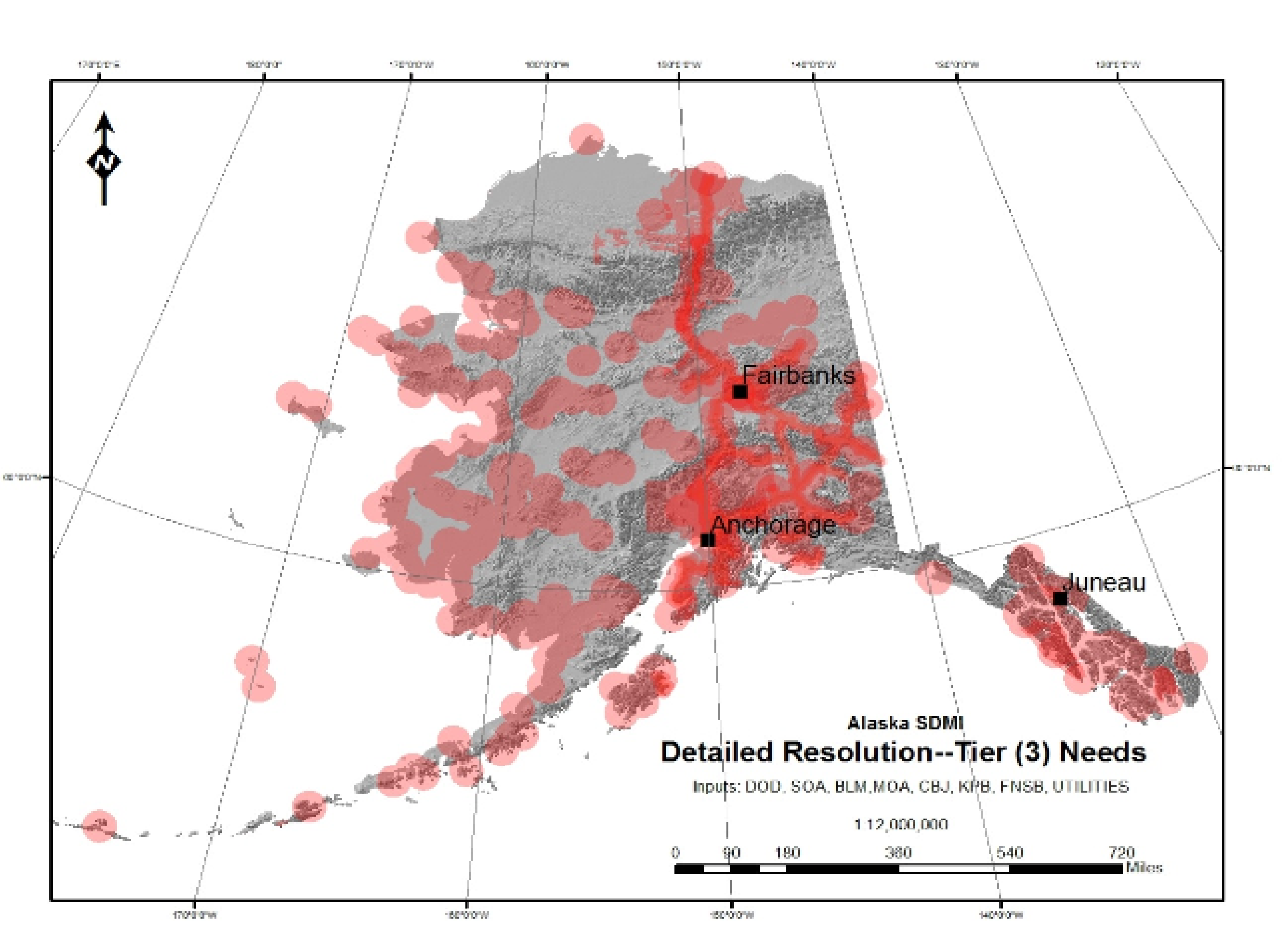

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CONCLUSIONS

- **This is a statewide program serving State, Federal, Alaska Native and other stakeholders.**
- **A 1:24,000 scale image map, 2.5m – 5m resolution, multi-spectral, updated no less often than every 3 - 5 years is a consensus requirement.**
- **All existing commercial systems can meet the 1:24k requirement with adequate DEM and ground control given collection geometry constraints.**
- **Larger scale image maps (higher resolution) will be required for regional 1m – 2.5m or project 0.5m – 1m work.**
- **Swath / footprint size matters to classification applications** (wetland delineation, fire fuel modeling etc.) **based on spectral continuity.**
- **Orthorectification and mosaicking costs are not insignificant.**
- **Some applications require leaf-off or stereo imagery.**
- **Ground receiving stations (virtual or real) provide benefits.**

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questions?

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