The Challenges and Joys of Mapping America's Last Frontier

An interview with Dr. Dave Maune, Project Manager for Alaska Statewide IfSAR Mapping

"Why was Alaska never previously mapped to National Map Accuracy Standards?"

Although all other states had USGS 1:24,000-scale topographic quad maps produced to National Map Accuracy Standards (NMAS) as well as large-scale orthophotos refreshed every few years to modern digital mapping standards, Alaska has never had statewide orthophotos, and its 1:63,360-scale topo quad maps from USGS did not satisfy NMAS for several reasons: (1) lack of cloud-free stereo imagery; (2) lack of photo-identifiable ground control; and (3) because photogrammetric block triangulation and GPS technologies hadn't been invented yet when USGS produced Alaska's quad maps many decades ago. Recent attempts to produce digital orthophotos by draping satellite imagery over DEMs from the National Elevation Dataset (NED) failed because the NED was too inaccurate to support orthorectification, as demonstrated by Figure 1.

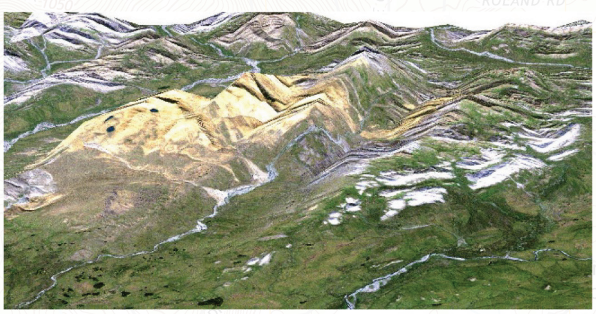


Figure 1. The NED's low-res 60m DEM had horizontal errors as large as one mile in the Brooks Range, shown here. When draping satellite imagery over a DEM from the NED, some rivers flowed uphill and not through valleys as they should. Image courtesy of UAF GINA.

Figure 2. Looking up at Denali (20,310 ft.) from the base camp at 7,000 ft. from which 4 surveyors traversed ~83 miles horizontally and climbed ~6 miles vertically (including back-and-forth caching) while carrying over 700 pounds of equipment each year to the peak to perform GPS & GPS surveys in 2015 and 2016. Image courtesy of CompassData.

> *"A Government cannot do any scientific work of more value to the people at large, than by causing the construction of proper topographic maps of the country," by John Wesley Powell, 2nd Director of USGS, in his testimony to Congress on December 5, 1884."*

Why was Dewberry selected to solve Alaska mapping problems?

At the Alaska Surveying and Mapping Conference in 2008, I used ASPRS' DEM Users Manual (that I authored/edited) as a reference, explaining why the topographic layer is foundational for producing orthoimagery and other mapping layers. The DEM Users Manual explained the need for establishing DEM requirements first -- prior to deciding what DEM technology to use. Alaska then hired Dewberry to produce the Alaska DEM Whitepaper. Contrary to my lidar recommendations elsewhere, the Alaska DEM Whitepaper recommended aerial IfSAR statewide for Alaska because our requirements analysis indicated that DSMs and DTMs with 20' contour accuracy satisfied known statewide requirements, including immediate aerial navigation and safety requirements of the Federal Aviation Administration (FAA), and because IfSAR could meet this requirement while mapping through persistent clouds. Alaska then asked USGS to contract with Dewberry to execute statewide IfSAR mapping under its USGS GPSC contract.

What were your initial challenges?

Despite the logistical challenges in GPS surveying IfSAR prism reflectors and QA/QC checkpoints throughout vast remote areas of Alaska, the Dewberry team knew that we could do the job technically, but we didn't know how much it would cost or who would pay for it. I authored the Alaska DEM Funding & Implementation Plan that recommended cost sharing among multiple federal and state stakeholders, and Dewberry worked with its two IfSAR subcontractors to submit a technical proposal to USGS. We estimated it would cost $77.3M to map Alaska over a 2-year period, with Fugro EarthData mapping the most-difficult 23% of the state using its GeoSAR system, and Intermap Technologies mapping the less-difficult 77% of the state using its (three) STAR systems. Fugro's perceived advantage was that the GeoSAR included both X-band and P-band; combined with GeoSAR's lidar profiler, the P-band should be better able to map DTMs through dense forests, but Fugro did not have a mature production line for doing this. Intermap's advantage was that it had produced NEXTMap®Europe, NEXTMap®Britain, and NEXTMap®USA over 49 states; it had a mature production line for delivering standard products that exceeded USGS specifications for mid-accuracy DEMs, even though it used algorithms to estimate vegetation heights for production of DTMs from X-band IfSAR that maps top reflective surfaces (DSMs).

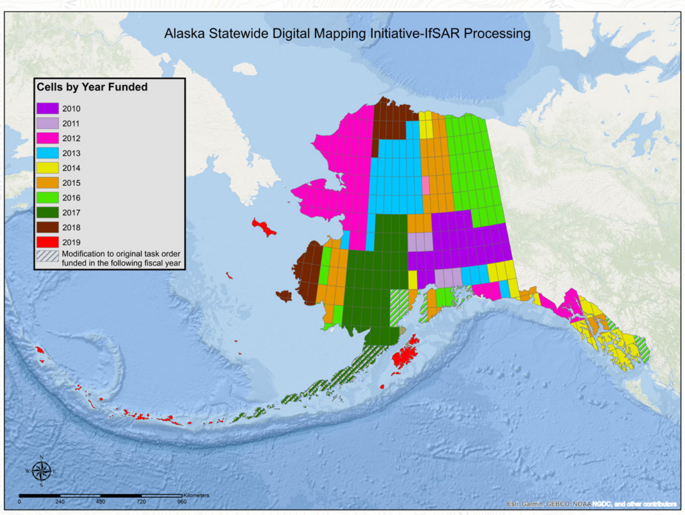
Photogrammetric Engineering & Remote Sensing
Vol. 86, No. 4, April 2020, pp. 202–207.
0099-1112/20/202–207

© 2020 American Society for Photogrammetry and Remote Sensing

doi: 10.14358/PERS.86.4.202

"What challenges did you face once you received funded task orders?"

We first needed to develop consensus on standards, specifications, priorities and deliverables. Dewberry provided overall project management and rigorous QA/QC, using checkpoints from JOA Surveys. Data were delivered in the Alaska Albers projection, then converted to multiple file formats for USGS and NGA. Elevation data was delivered in both orthometric and ellipsoid heights, using Geoid09 throughout for consistency. Intermap's Ortho-rectified Radar Images (ORIs) had 62.5-cm resolution, whereas Fugro's ORIs had 2.5-meter resolution – both better than USGS' 5-meter resolution requirement. Fugro delivered hydro-enforced DSMs and DTMs that met USGS' hydro specifications whereas Intermap's standard hydro masks exceeded USGS specifications for lakes and double-line streams. USGS received data that exceeded specifications, but this caused edge-join issues and inconsistencies along seam lines between the two firms. Mapping the easier terrain, Intermap routinely exceeded accuracy specifications whereas Fugro struggled to satisfy accuracy requirements partly because the P-band didn't just penetrate vegetation, but sometimes also penetrated the ground, depending on soil wetness. Fugro developed an X-band/P-band hybrid model for DTMs, but some issues remained. GeoSAR appeared to lower Denali's peak elevation by 60+ feet, possibly from IfSAR foreshortening, shadow or layover. This caused Dewberry to launch two expeditions to climb Denali in 2015 to GPS survey the official elevation of the top of the ice and snow (at 20,310 ft), returning in 2016 to install a USGS survey monument at Windy Corner and to use ground penetrating radar (GPR) to measure the 6.1-meter depth of ice and snow on the peak. Both years, Blaine Horner of CompassData led 4-person teams that carried equipment loads of over 700 pounds from their base camp at 7,000', to the peak, under extremely difficult conditions.



In addition to these technical and logistical challenges, USGS lacked the funding necessary to acquire the data efficiently in large contiguous blocks over a 2-year acquisition period. Instead, as funds became available from diverse stakeholders, funding was received in piecemeal fashion for smaller blocks each year between 2010 and 2019 (see Figure 3) for annual project areas. By the time funds were available in 2019 for mapping of Kodiak Island which we had planned to map with GeoSAR (because of the rugged terrain and dense forests), GeoSAR had already been retired from service by Fugro and was no longer operating commercially. Intermap did the best they could to map Kodiak Island with X-band IfSAR only.

Because funds were received so erratically in small, inefficient acquisition blocks, members of the Dewberry team acquired much data on speculation, taking financial risks and not knowing whether they would ever be paid.

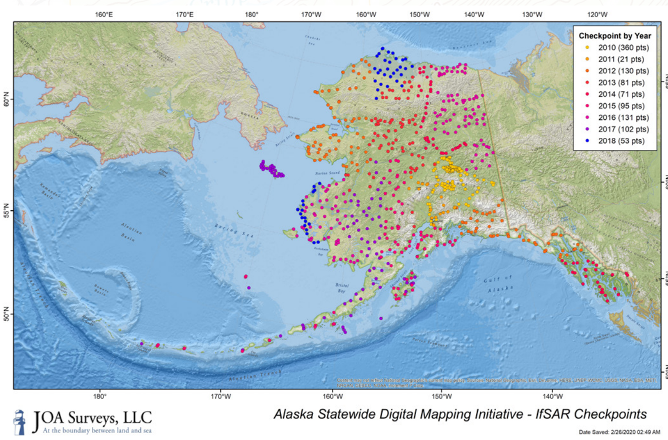


Figure 5. JOA Surveys efficiently surveyed 1,044 QA/QC checkpoints in remote terrain within each of the cells mapped by Intermap and Fugro.

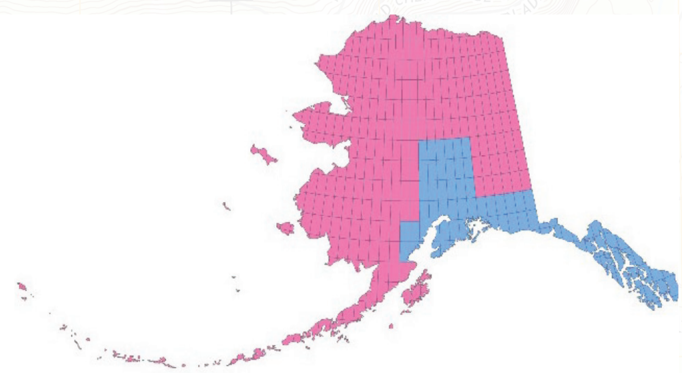


Figure 4. Intermap efficiently mapped all Alaska 1-degree cells shown in pink, and Fugro efficiently mapped all cells shown in blue.

Figure 3. Rather than being funded efficiently for large contiguous blocks in two years, small non-contiguous blocks were mapped each year between 2010 and 2019 as funds became available from different stakeholders. This also impacted Dewberry's ability to efficiently acquire annual QA/QC checkpoints in advance of accuracy testing.

What are your greatest joys, now that the project is complete?

My biggest joy is that we successfully mapped all of Alaska, consistently meeting or exceeding USGS' specifications, at a total cost of $66.3M, rather than the $77.3M originally estimated. This is a tribute to cost efficiencies by all involved.

My second joy is knowing the vast improvement in usability of IfSAR DEMs compared to the prior DEMs from the NED.

- In preparing the initial Alaska DEM Whitepaper, I learned of the importance of hydro features to Alaskans. Figure 6 (courtesy of Intermap) shows the richness of the hydro features from IfSAR, compared with sparse hydro features in the NED. Hydro-enforced IfSAR DTMs are now being used to update National Hydrography Datasets (NHD) throughout Alaska.
- I also learned of the importance of being able to map through clouds and produce digital orthoimages. Figure 7 shows how higher-resolution greyscale IfSAR ORIs can be used to pan-sharpen lower-resolution color satellite imagery; and Figure 8 demonstrates how IfSAR ORIs can be used to produce color orthophotos, even when satellite images are cloudy.

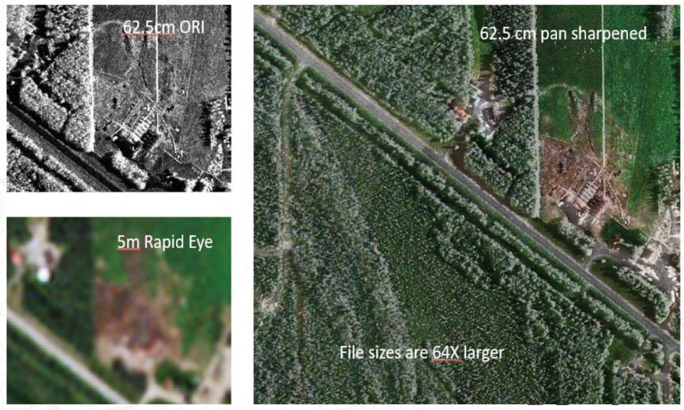


Figure 7. This figure demonstrates how to pan-sharpen 5m color satellite imagery with 62.5-cm greyscale IfSAR ORIs.

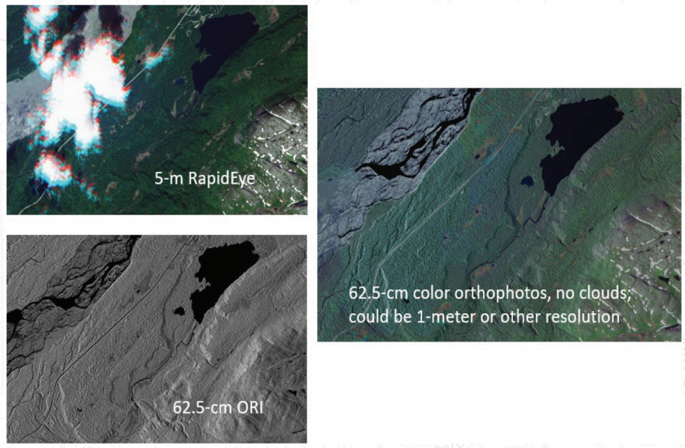
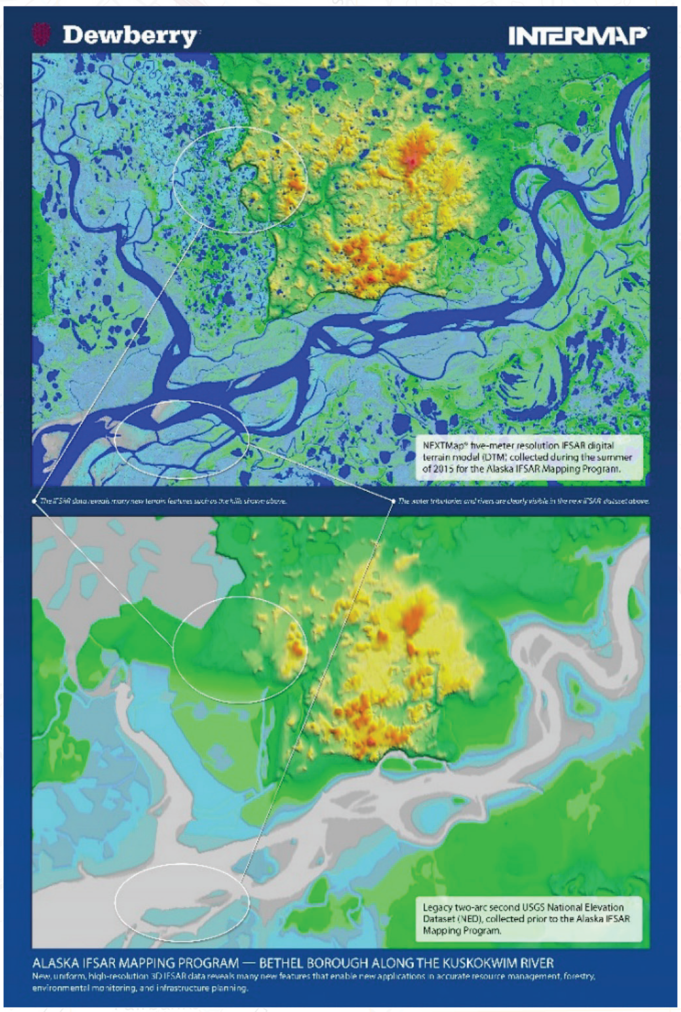


Figure 8. This figure demonstrates how IfSAR ORIs can be used to pan-sharpen cloudy satellite imagery – mapping through the clouds.



> *"The detailed mapping of elevation in the State of Alaska significantly improves the economy, quality of life and safety of our largest State. It satisfied needs for flood modeling, flight safety, precision forestry, landslide modeling, critical minerals assessments, natural resource assessments, and transportation and infrastructure development. And while the data that has been collected has significant value today, it will be even more valuable 20, 30 or 50 years from now as it will provide a baseline for which changes can be measured. For example, changes in shoreline, glacial mass, subsidence and hydrologic regime. It raises Alaska to the modern mapping standard and it opens the door for the next chapter in the future of Alaska, a future that recognizes Alaska as a natural resource wonder, a thriving economy and strategic national security interest." By Kevin T. Gallagher, USGS Associate Director, Core Science Systems.*

Figure 6. Aerial IfSAR (top) of Kuskokwim River compared with the prior NED (bottom). IfSAR hydro features are extremely rich.

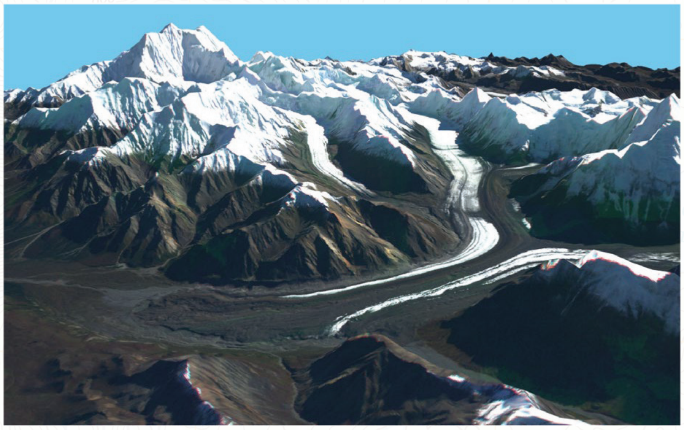


Figure 9. This is a satellite image draped over the IfSAR DTM of Mt. Hayes, then viewed from a perspective selected by Dewberry. Compare this image with Figure 1 to see the vast improvements.

Figure 10. The top image shows a satellite image draped over the IfSAR DTM of Denali's peak. The lower image shows a Denali fly-by photograph taken by E-Terra. The similarity is remarkable.

My third joy is in finding that everything now fits when draping satellite imagery over IfSAR DTMs. See Figures 9 and 10.

My fourth joy is exhilaration received from Blaine Horner's two mountaineering expeditions to perform GPS and GPR surveys to officially survey Denali's elevation at 20,310 ft and the depth of the ice/snow at 6.1 meters. Whereas many have died attempting to climb Denali with no extra heavy burden to carry, Blaine Horner's two teams, shown in Figures 11 and 12, carried over 700 pounds of car batteries, power tools and other heavy equipment both years to the top. During his 2016 expedition, Blaine even won NPS' Mislow-Swanson Denali Pro Award for saying the lives of two badly injured European climbers.

My fifth joy is knowing the 7.5-minute 1:25,000-scale US Topo map series of Alaska, to include statewide orthoimagery, will be completed in 2021 (Figures 14 and 15 courtesy of USGS). With IfSAR completed in 2020, USGS will acquire commercial satellite imagery in 2021 for orthorectification to the IfSAR. The Dewberry team is proud of its accomplishments in providing the accurate topographic foundational layer to which other layers now fit. (Figure 16).

Figure 11. Blaine Horner (left) with Rhett Foster, Udi Karriere and Tom Heinrichs prior to flying to the Base Camp at 7,000' for their climb to GPS survey Denali's peak in 2015.

Figure 12. Kristen Schild (left) with husband Seth Campbell, Patrick Saylor and Blaine Horner at the Base Camp prior to their climb to GPR survey the ice/snow depth on Denali's peak in 2016.

Figure 13. In 2016, Blaine Horner installed and surveyed a USGS survey marker at Windy Corner and then rescued two badly injured European climbers who had fallen.

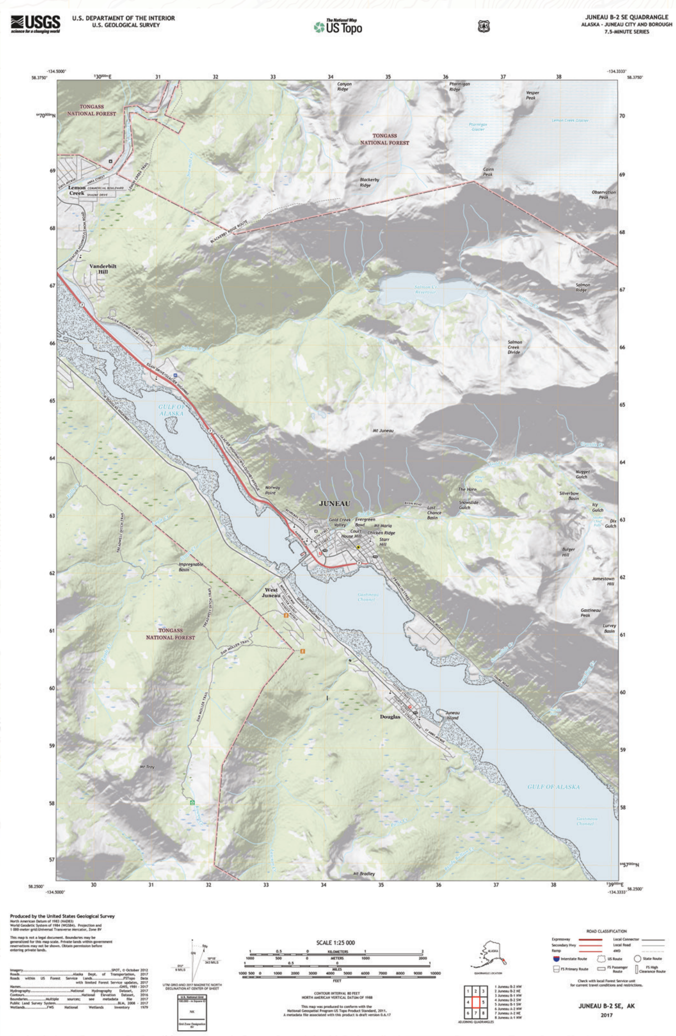


Figure 14. US Topo of Juneau with shaded relief turned on.

Figure 15. Glaciated US Topo with orthoimagery layer turned on.

> *"This data and information is provided to the world, license-free, in the public domain, for its use and application in all areas previously mentioned as well as recreation and scientific research. These maps are easily downloaded electronically and used for a wide variety of applications from recreational, to city planning, to emergency response. Lastly, data layers such as hydrography, roads, trails, boundaries and other data layers will be enhanced because of the new, more detailed elevation data." By Kevin T. Gallagher, USGS.*

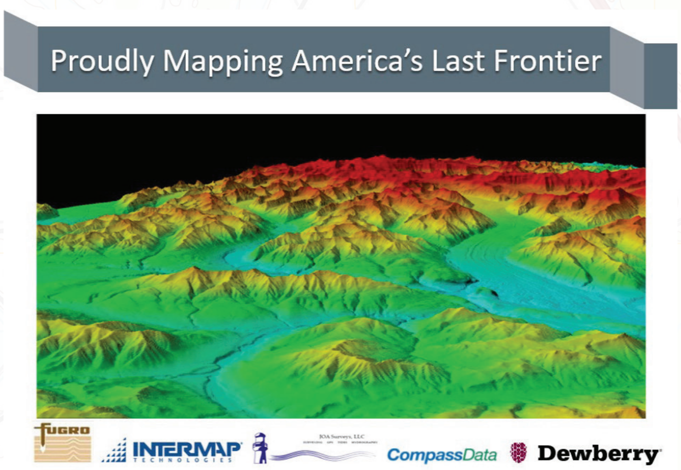


Figure 16. the proud Dewberry team includes Fugro, Intermap, JOA Surveys and CompassData.

Figure 17. Lt Gov Mead Treadwell briefing the Alaska Mapping Roundtable on June 28, 2012 in Washington D.C. Image courtesy of USGS.

Lastly, it gives me great joy that America's Last Frontier was mapped with such outstanding teamwork, not just by the Dewberry team but by numerous federal and state stakeholders. In addition to organizing Skybreaking events that showcased the SAR aircraft and technology, Nick Mastrodicasa of AK DOTPF arranged for OMB and over 20 other federal agencies to meet for the first Alaska Mapping Roundtable in Washington, D.C. in 2012 (Figure 17). After briefings by Alaska's Lt Gov Mead Treadwell, Dave Maune, Nick Mastrodicasa and briefers from USGS, agency executives unanimously agreed on the urgent need for accurate mapping of Alaska which holds major natural resources and is becoming more vital each year as marine navigation routes are opening through the Arctic and as the search expands for mining of critical minerals for USGS' Earth Mapping Resources Initiative (Earth MRI). Ultimately, $66.3M in funding was received from USGS, the State of Alaska, NRCS, BLM, NPS, DOD, USFS, and FWS. Senator Lisa Murkowski led the effort to obtain needed funding at the federal level. Project success can be attributed to collaboration by all involved. This was a total team effort and its major reason for success.

Dr. Dave Maune, is an Associate Vice President at Dewberry Engineers, Inc., headquartered in Fairfax, Virginia, with more than 50 locations and 2,000+ professionals nationwide. Dave is best known as the editor and principal author of all three editions of The DEM Users Manual published by ASPRS in 2001, 2007 and 2018, and as the author of the National Enhanced Elevation Assessment (NEEA) that provided the blueprint for USGS' 3D Elevation Program (3DEP) based on QL5 IfSAR of Alaska and QL2 lidar elsewhere in the U.S. Dewberry is a full-service A/E firm that specializes in geospatial technologies, products and services, including remote sensing data acquisition and processing, data analytics, digital orthophotography, emergency response, geospatial benefit-cost analyses, GIS, topographic and hydrographic mapping and surveying, and independent QA/QC of geospatial data provided by others.