A GEOSPATIAL STRATEGY TO LOCATE FUTURE CHINESE ICBM SILO FIELDS

by
Jason G. Faust

A capstone project submitted to Johns Hopkins University in conformity with the requirements for the degree of Master of Science in Geospatial Intelligence

Baltimore, Maryland
December 2021

Abstract

This Capstone report analyzes two recently constructed missile silo fields in China in an effort to identify key geospatial and geological characteristics that can be used to define a search strategy for future silo field construction. This report incorporates statistical analysis techniques that will constrain the areas under consideration based on nearness to railroads which will then incorporate multiple raster layers that will characterize the region constrained region, and then remove parcels of land that do not have the adequate characteristics to accommodate rapid silo construction. Based on the size of the delivery system(s) the People's Liberation Army Rocket Force (PLARF) are installing, the biggest factor in this study will be depth to bedrock. Other factors include surface slope, land cover classification, and whether a given site is within range of conventional US missiles. It is important to researchers and analysts in and outside the Intelligence Community to have a systematic method for defining search strategies, and this report serves as a foundational first step in that effort.

Primary Reader and Advisor: Jack O'Connor

Secondary Reader: Anonymous

Contents

1. Key Intelligence Question(s)

What are the geospatial and geological characteristics of the recently constructed Hami and Yumen Missile Silo Fields? Based on the characteristics of these two silo fields and historical ICBM sites in the PRC, where are likely locations for other fields to be constructed?

2. Key Judgment(s)

The development of the Hami and Yumen silo fields will continue to have a significant geopolitical impact and will add strain to the international community's relationship with China - specifically the United States and India. A systematic method to identify future silo field construction, and task collection efforts will improve future geospatial discoveries.

3. Background

3.1 China and Weapons of Mass Destruction

The People's Republic of China has been developing, producing, and testing nuclear weapons since the First Taiwan Strait Crisis of 1954-1955, and tested its first nuclear weapon in 1964. The live testing continued until 1997 when the PRC entered the Comprehensive Test Ban Treaty (CTBT). The current number of PRC nuclear weapons is unknown, but the most recent estimate in 2015 by the Federation of American Scientists places the arsenal at roughly 240 warheads[1]. If this estimate is correct, it would give the PRC the fourth largest nuclear arsenal among the five nuclear weapon states acknowledged by the Treaty on the Non-Proliferation of Nuclear Weapons.

In 2011, the PRC published a paper that repeated its nuclear policies of maintaining a minimum deterrence strategy with a no-first use pledge[2]. The PRC has not defined what a "minimum deterrent" policy means, which is a considerable gray area. Recent People's Liberation Army Rocket Force

[1] Hans M. Kristensen & Robert S. Norris (2011) Chinese nuclear forces, 2011, Bulletin of the Atomic Scientists, 67:6, 81-87, DOI: 10.1177/0096340211426630

[2] "China Publishes White Paper on Arms Control". China.org.cn. September 1, 2005. Archived from the original on May 11, 2013. Retrieved December 1, 2021.

(PLARF) deployments such as expansive silo complexes (Hami & Yumen), solid-fueled Intercontinental Ballistic Missiles (DF-41), intermediate range ballistic missiles (DF-26), and developments such as hypersonic delivery vehicles (DF-ZF) are at best incongruous and at worst ominous.

There were reports in 2015 that the PRC was retrofitting the road-mobile DF-41 to rail-mobile, and silo based launching platforms.[3] Five years later, the Federation of American Scientists reported that PLARF was in fact building the silo fields at Hami and Yumen for the DF-41.[4] Based on this open-source reporting, this report will use the dimensions of the DF-41 below as one of the factors to prioritize search regions.[5] Based on the length of the DF-41 (20-22 meters), one of the key assumptions in this report will be a minimum depth to bedrock of 25 meters.

Dongfeng-41 (DF-41) Intercontinental Ballistic Missile	
Mass	80,000 kilograms (180,000 lb.)
Length	20-22 meters (65-72 ft)
Diameter	2.25 m (7 ft 5 in)
Operational Range	12,000–15,000 km (7,500–9,300 mi)
Maximum Speed	30,626 km/h (19,030 mph)

4. Framing the Discussion

4.1 What are China's motivations and how do they fit into an overall strategy?

As of late, experts in and outside of government have questioned China's publicly stated "minimum deterrence" policy and "no-first-use" pledge. China will not in the near future achieve parity with Russian or US stockpiles of nuclear weapons, but their documented actions show an increase in their delivery systems, and by inference, an increase in their stockpile. Whether they are seeking parity or

[3] Gady, F.-S. (2016, January 5). China tests new rail-mobile missile capable of hitting all of Us. – The Diplomat. Retrieved December 1, 2021, from https://thediplomat.com/2016/01/china-tests-new-rail-mobile-missile-capable-of-hitting-all-of-us/.
[4] Korda, M., & Kristensen, H. (2021, July 26). China Is Building A Second Nuclear Missile Silo Field. Federation Of American Scientists. Retrieved December 1, 2021, from https://fas.org/blogs/security/2021/07/china-is-building-a-second-nuclear-missile-silo-field/.
[5] Center for Strategic and International Studies. (2021, July 31). DF-41 (Dong Feng-41 / CSS-X-20). Missile Threat. Retrieved December 1, 2021, from https://missilethreat.csis.org/missile/df-41/.

superiority in nuclear weapons, is not yet clear, but they are on a comprehensive path forward to challenge the Russian and US positions.

China's ramp up of their nuclear weapons stockpile and more sophisticated delivery systems is nothing new with respect to the modern geopolitical arena. The Soviet Union created a similar climate during The Cold War, and the net effect was mutually assured destruction. China may be breathing new life to the international relations theory known as the "stability-instability paradox".[6] The United States still has a significant upper hand in this challenge due to ballistic missile submarines (SSBN), but China can still create a state of mutually assured destruction by constructing hundreds of missile silos and building out a SSBN fleet. This contemporary application of the stability-instability paradox might allow China to create strategic weapons parity with the United States and open the door for more conventional military options.

4.2 Cause for US Concern

After the withdrawal from Afghanistan in 2021, the United States set in motion major organizational changes to the Intelligence Community in order to best position themselves for the growing geopolitical threat faced by a more aggressive Beijing.[7] The US is particularly concerned about maritime travel in the South China Sea, a kinetic conflict on the Korean Peninsula, and President Xi's public desire to unify China and bring Taiwan back under Beijing's control. If the United States finds itself in a stability-instability paradox predicament with China, then they might have the latitude to pursue proxy wars or otherwise if there is a guarantee of mutual destruction with the United States.

For that reason, it is important that these developments play out in the public sphere so the US may have the political capital to bring Beijing to the negotiating table and have serious discussions on nuclear disarmament similar to the START treaties with the Soviet Union/Russia. There is also concern

[6] Kapur, S. (2017). Stability-instability paradox. In F. Moghaddam (Ed.), The SAGE encyclopedia of political behavior (pp. 799-801). SAGE Publications, Inc., https://www.doi.org/10.4135/9781483391144.n364
[7] Barnes, J. E. (2021, October 7). C.I.A. Reorganization to Place New Focus on China. The New York Times. Retrieved December 1, 2021, from https://www.nytimes.com/2021/10/07/us/politics/cia-reorganization-china.html.

amongst certain Pentagon officials that China may be pivoting away from their long stated “No First Use” policy declaration, but dissenters say that the expansion of silo-based systems intends to safeguard the survivability of its retaliatory nuclear forces. Either way, STRATCOM’s recent testimony to Congress suggests that it sees recent developments as destabilizing.[8]

> “To fully assess the China threat, it is also necessary to consider the capability of the associated delivery system, command and control, readiness, posture, doctrine and training. By these measures, China is already capable of executing any plausible nuclear employment strategy within their region and will soon be able to do so at intercontinental ranges as well. They are no longer a ‘lesser included case‘ of the pacing nuclear threat, Russia.”
>
> -Admiral Charles Richard, STRATCOM Commander

5. Analysis Factors

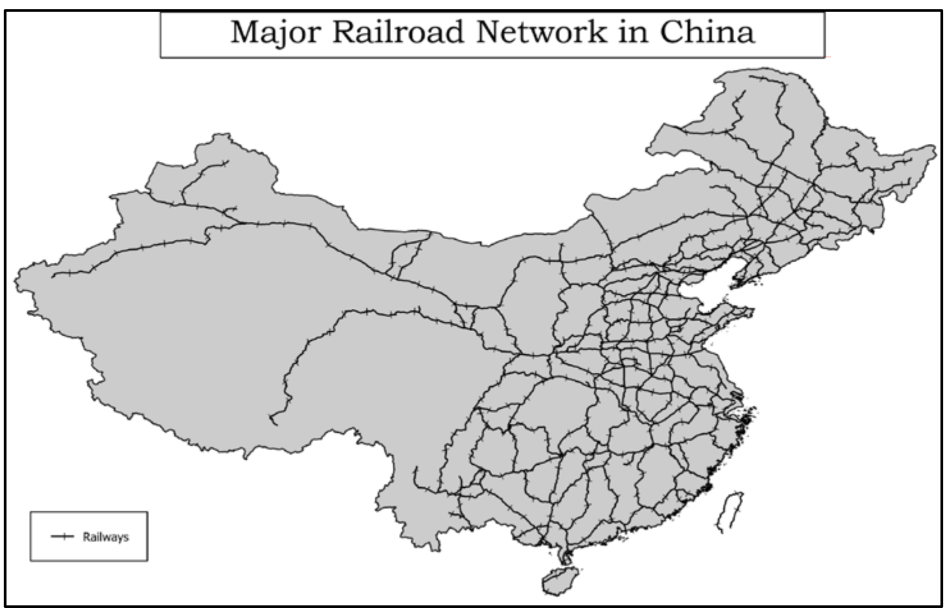
5.1 Objective

This study investigates the geospatial characteristics that the Hami and Yumen silo fields share, determines the extent that those characteristics overlap with other ICBM sites within China, and use that data to identify regions that lack features that would accommodate rapid construction of a silo field. The core of this analysis focuses on the fact that while you can build roads, railways, and change land cover, you cannot change geology. Constructing nuclear silos is obviously a very labor-intensive process, but the one factor that can severely impact the time to completion is the depth to bedrock. The Chinese have been able to surprise those in and out of the Intelligence Community by the speed they are able to construct silo fields, and that rapid time to completion is possible because the PLARF may have chosen areas with a bedrock depth suitable for rapid development. The variables covered below will identify several candidate regions that will inform future collection efforts in order to quickly identify the construction of additional silo fields.

[8] Kristensen, H. M., & Korda, M. (2021, September 1). China's nuclear missile silo expansion: From minimum deterrence to medium deterrence. Bulletin of the Atomic Scientists. Retrieved December 2, 2021, from https://thebulletin.org/2021/09/chinas-nuclear-missile-silo-expansion-from-minimum-deterrence-to-medium-deterrence/.

5.2 Transportation Networks

Constructing one silo, let alone over two hundred, requires a significant amount of infrastructure to be able to move around the silo components, relevant equipment, raw materials, and most importantly the manpower. The PLA was originally tasked with building out the railway system across the country. That responsibility was transferred to the China Railway Construction Corporation in 1984, but they continued to maintain a strong relationship with the PLA.[9] Since then the PRC has made significant investments in railroads throughout the country, but with an emphasis on the more heavily populated Eastern China. During the Cold War, the Strategic Rocket Forces of the Soviet Union largely constructed missile bases within 40-65 kilometers of the railroad which is the best use case for coming up with a search strategy as it relates to China. The Soviets did not build massive fields in one location as the Chinese are doing, but that is likely due to IMINT and GEOINT advancements that make it harder to hide Soviet style silos.



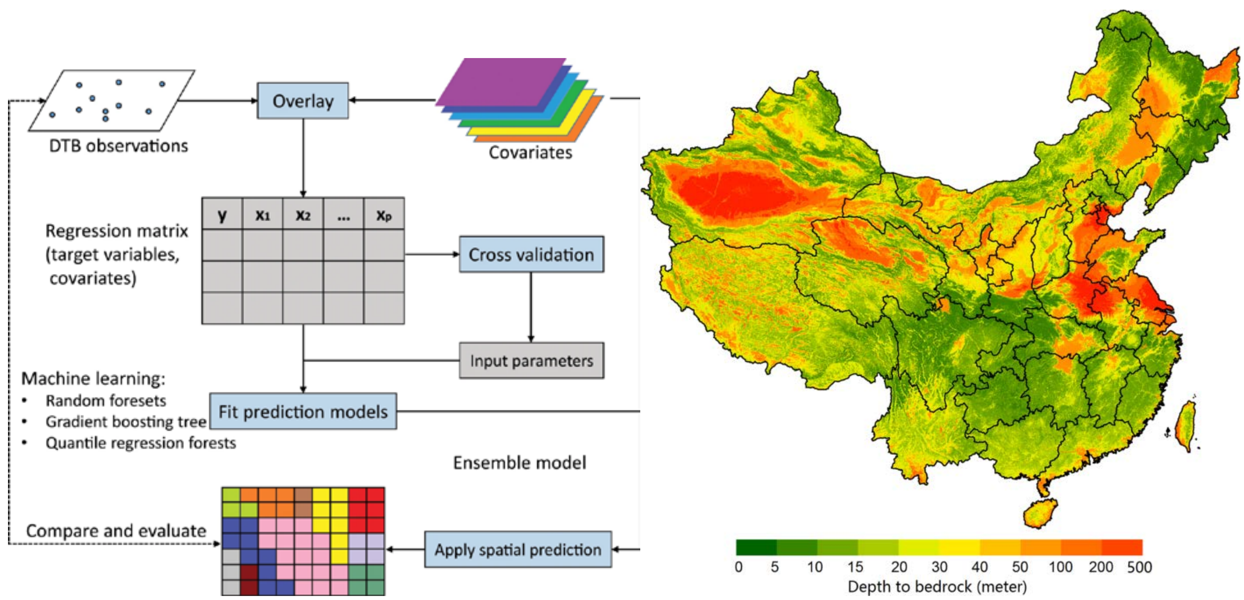
Major Railway Networks in China[10]

[9] Dorfman, Z., & Allen-Ebrahimian, B. (2020, June 24). Defense Department produces list of Chinese military-linked companies. Axios. Retrieved December 1, 2021, from https://www.axios.com/defense-department-chinese-military-linked-companies-856b9315-48d2-4aec-b932-97b8f29a4d40.html.

[10] Li, Yifan, 2016, "China High Speed Railways and Stations (2016)", https://doi.org/10.7910/DVN/JIISNB, Harvard Dataverse, V1

5.3 Depth to Bedrock

There is very little geospatial data on bedrock depth in China, but a few researchers from *Scientific Data* used borehole data from the Chinese National Important Geological Borehole Database to reason about this metric.[11] They devised a sampling scheme to take a total of 6,382 Depth to Bedrock (DTB) observations spread throughout mainland China. The figures below provide a high-level framework of the workflow to produce this layer, a map of the final product which was a 100-meter resolution raster layer that provided the predicted bedrock depth measured in meters. This layer will be at the core of the analysis for existing silo locations, in terms of calculating statistics such as the mean depth to bedrock for the Hami and Yumen silo fields. This layer will also serve as a core dataset for forecasting the locations of potential silo fields based on the results of the statistical analysis, and the dimensions of the DF-41 which requires a minimum depth of 25 meters based on the estimated length of 20-22 meters.



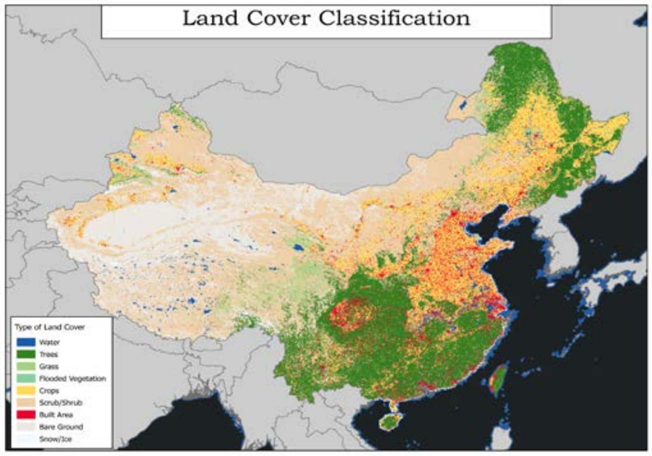
5.4 Land Cover & Slope

As part of the Living Atlas collection, ESRI has developed a high-resolution land cover/land use raster dataset that has up to date global coverage. This layer served as another key reduction variable in

---

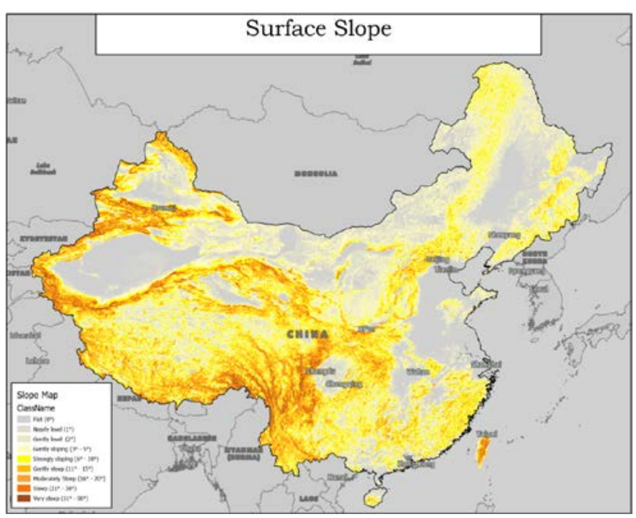
[11] Yan, F., Shangguan, W., Zhang, J. et al. Depth-to-bedrock map of China at a spatial resolution of 100 meters. Sci Data 7, 2 (2020). https://doi.org/10.1038/s41597-019-0345-6

the search strategy. The various land cover classifications, and whether or not they were included in the forecasting effort are listed in the table below.



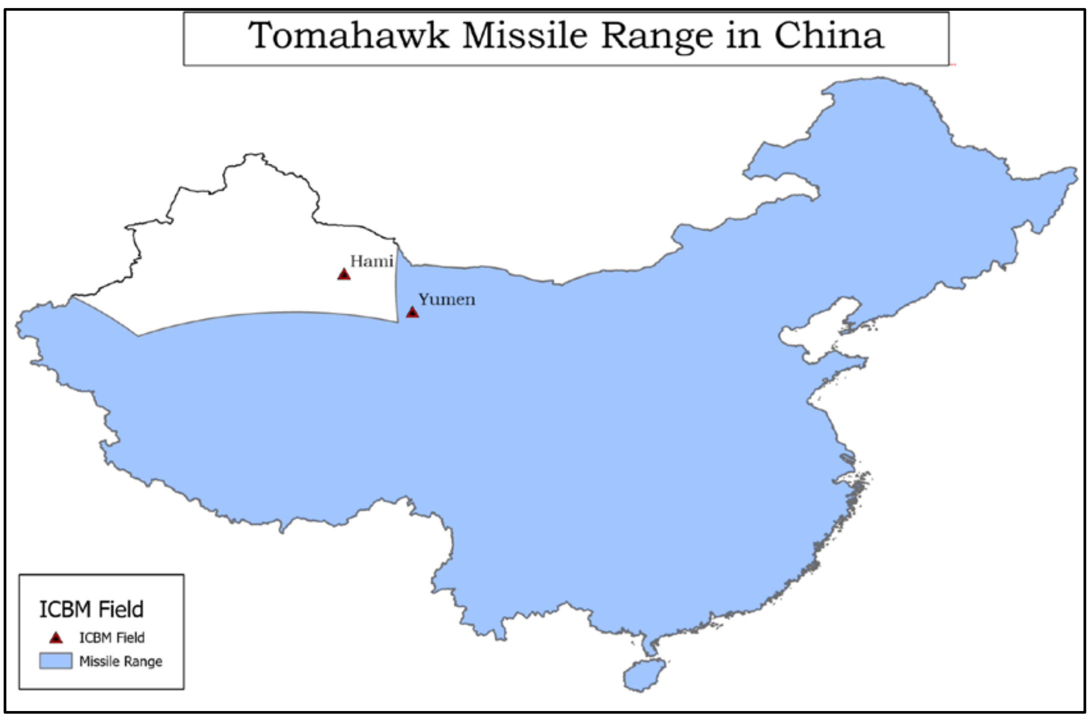
Land Cover Type	Water	Trees	Grass	Flooded Vegetation	Crops	Shrub/ Scrub	Built Area	Bare Ground	Snow/Ice
Removed	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes

With respect to slope, a Digital Elevation Model had to be created from scratch, and then that layer was used to interpolate surface slope at a 0.5-kilometer resolution. It was vital that this layer be incorporated since the Chinese have been building thee silo fields in locations one would expect, with bare ground and a minor slope. Using this layer, the slope distribution of both silo fields reports a max value of 5 degrees. The slope layer was manipulated to remove all raster tiles with a slope greater than five degrees, and the result was used to clip the raster layer with the remaining attributes.



5.5 Survivability

One of the pressing questions surrounding the construction of the silo fields is why they are so far inland. It is common for silos or silo fields to be in remote locations, but the deeper in the interior of the country, the more operational range of the missiles is diminished. In terms of US and its allies countermeasures, there are two options. The first is a nuclear exchange involving SSBN's, and other strategic nuclear delivery systems. The second option is survival against a maritime based strike involving Tomahawk missiles. Based on unclassified data, the operational range of a Tomahawk is ~2,500 kilometers.[12] If that estimated range is accurate, Hami would be outside their range by roughly 260 kilometers. The Yumen site is within the range of a strike, but it is right on the range limit. These facts combined with China's development of a new early-warning system[13], giving missile defense systems a higher chance of success, makes the survivability argument even stronger.



Operational Range Respects International Waters Boundaries

[12] Center for Strategic and International Studies. (2021, July 31). *Tomahawk*. Missile Threat. Retrieved December 1, 2021, from https://missilethreat.csis.org/missile/tomahawk/.

[13] Korolev, A. (2020, November 19). *China–Russia cooperation on missile attack early warning systems*. Economics, Politics and Public Policy in East Asia and the Pacific. Retrieved December 2, 2021, from https://www.eastasiaforum.org/2020/11/20/china-russia-cooperation-on-missile-attack-early-warning-systems/

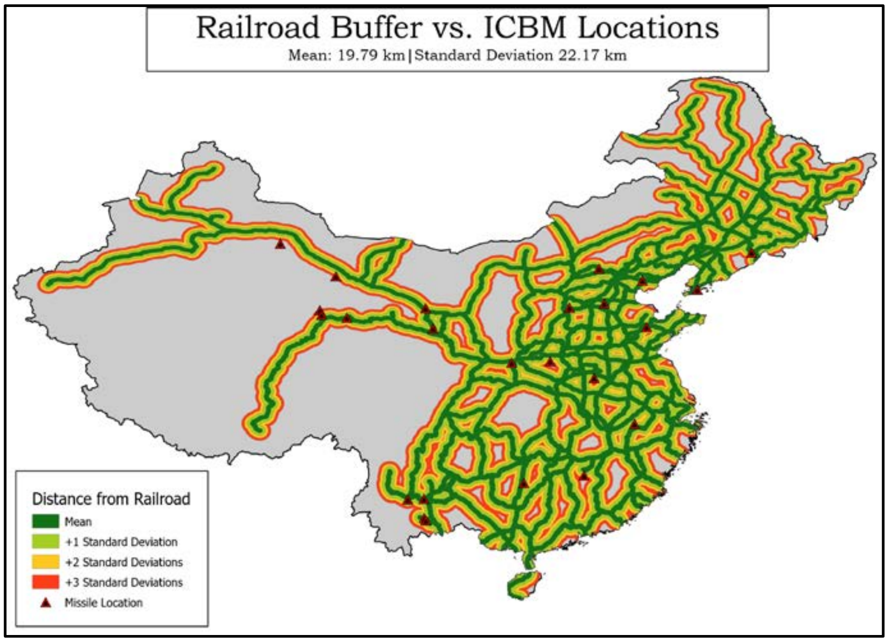
6. Methodology

6.1 Tools Used

Most of this analysis relies on raster datasets, and fortunately ArcGIS Pro has a wide selection of raster management tools. While the toolkit has a variety of applications, this report is constrained to only a few because the files are so large computations would need to be run on hardware other than a local machine for the turnaround time to be reasonable. For that reason, this report does not do much heavy lifting in terms of raster creation, but rather alters individual raster values for the sole purpose of narrowing down the size of candidate regions backed by reasonable assumptions concerning depth to bedrock, land cover suitability, and surface slope.

6.2 Statistical Analysis

To mitigate risk of removing promising candidate regions, there needed to be a methodical statistical approach. During the Cold War, Soviet silo construction largely depended on proximity to the Trans-Siberian Railway. The sizes of Soviet silo fields were much different than the recent developments in China, but they did tend to be located relatively close to the railway system throughout the Soviet Union. For that reason, it is logical to use the locations of all missile locations in China as a starting point for down-selection. The "Generate Near Table" was used to calculate the nearest distance of each individual silo to the railroad. Those values ended up taking on a "skewed right" distribution meaning that the majority of the silos were relatively close to the railroad. A mean distance of roughly twenty kilometers was observed, and a standard deviation of twenty-two kilometers. The values used to create a buffer layer around the railroad network are in the graphic below. Exclusively using the mean distance with only twenty-two observations would have resulted in excluding a large region, so the buffer included the mean and three standard deviations away from the mean.



Existing ICBM Deployment Locations and Region Under Consideration[14]

The second problem this report had to address was the size of a potential silo field. The "Average Nearest Neighbor" tool was used to calculate the average distance, or spacing, between each individual silo. The Hami complex is symmetrical throughout, but the Yumen site is distributed across two different locations so Yumen North and Yumen South were treated as independent sections. These values were used to calculate the size of each individual silo parcel, and expand that in intervals of forty, sixty, eighty, and one hundred silos. The table below highlights the size of each silo parcel, and the required size of a prospective facility based on the calculated values.

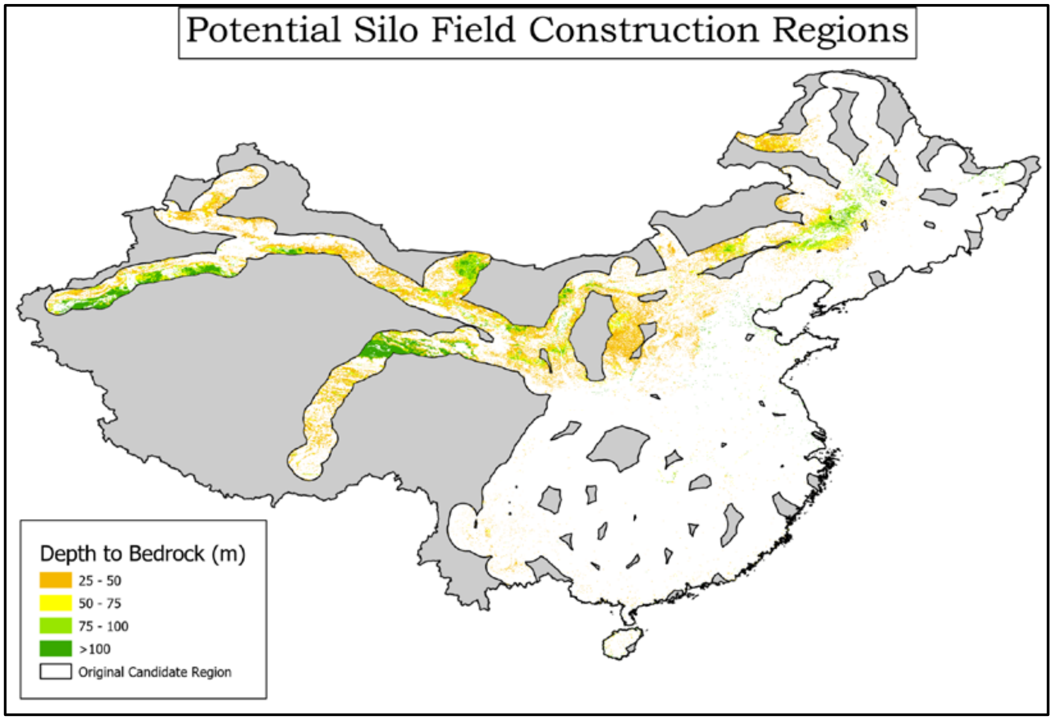
	Mean Distance between Silos (km)	Parcel Size (km^2)	40 Silo Field (km^2)	60 Silo Field (km^2)	80 Silo Field (km^2)	100 Silo Field (km^2)
Hami	2.60	6.78	271.37	407.05	542.74	678.42
Yumen North	3.72	13.87	554.62	831.93	1,109.24	1,386.55
Yumen South	3.73	13.90	555.84	833.76	1,111.68	1,389.60
Averages	3.35	11.52	460.61	690.91	921.22	1,151.52

[14] Kristensen, H. (n.d.). *Chinese Missile Facilities*. Missile Facilities - China Nuclear Forces. Retrieved September 12, 2021, from https://nuke.fas.org/guide/china/facility/missile.htm

6.3 Leveraging Statistical Analysis to make Down-Selections

All the steps mentioned above culminate with making significant downselection to the raw raster files. The most important variable this study focuses on is depth to bedrock. The first step is to use the "Extract by Mask" tool to have the raster include only tiles that are overlaid by the railroad buffer polygon above. Next the "Set Null" tool was used to assign "NoData" to every raster tile that has a depth to bedrock value less than the required 25 meters. Then the "Extract by Mask" tool was used again to only select land cover raster tiles that fall within the railroad buffer. Similar to the bedrock file, the "Set Null" tool was used to assign a "NoData" value to all the raster tiles that do not have a suitable surface type. The graphic below reflects the first stage of analysis concerning bedrock depth and land cover type and demonstrates how effective land cover and bedrock depth acts as a simple downselection variable.

Now that there are two independent layers with pixel values suitable for silo field construction, the raster files must be combined. This is done by using the "Combine" tool that will join the attribute tables of the two rasters while maintaining the high-resolution of the bedrock file. The final down-selection step includes incorporating the slope of a given raster tile. Other nations, including China, construct missile silos in mountainous areas but the most recent developments suggest that the Chinese are constructing in areas with a slope of less than five-degrees. To incorporate this data, the same workflow as mentioned above was used including Extract by Mask, Set Null, and then Combine to provide raster tiles that have sufficient depth to bedrock, suitable land cover, and a slope similar to the Hami and Yumen sites.



Regions that satisfy requirements for silo construction

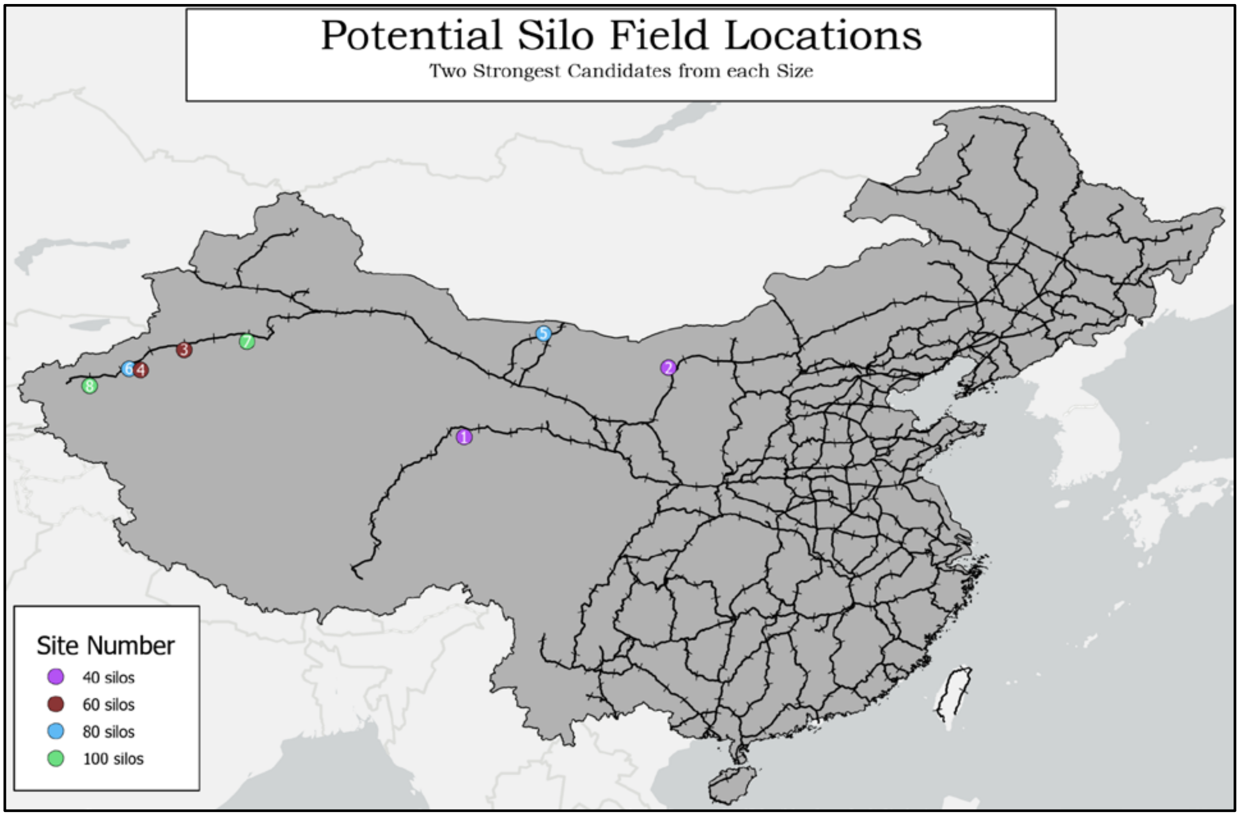
7. Results

7.1 Locate Regions Tool

The most important part of manipulating and combining all these raster files is being able to use them programmatically to locate areas that are most suitable for silo construction. The Locate Regions tool is capable of identifying the most suitable regions, or groups of contiguous raster cells, from an input utility raster that satisfies a specified evaluation criterion that meets a specific shape and size constraint. In this report's use case, the evaluation criterions include the depth to bedrock, and the size of a prospective field based on the statistics in the section above.

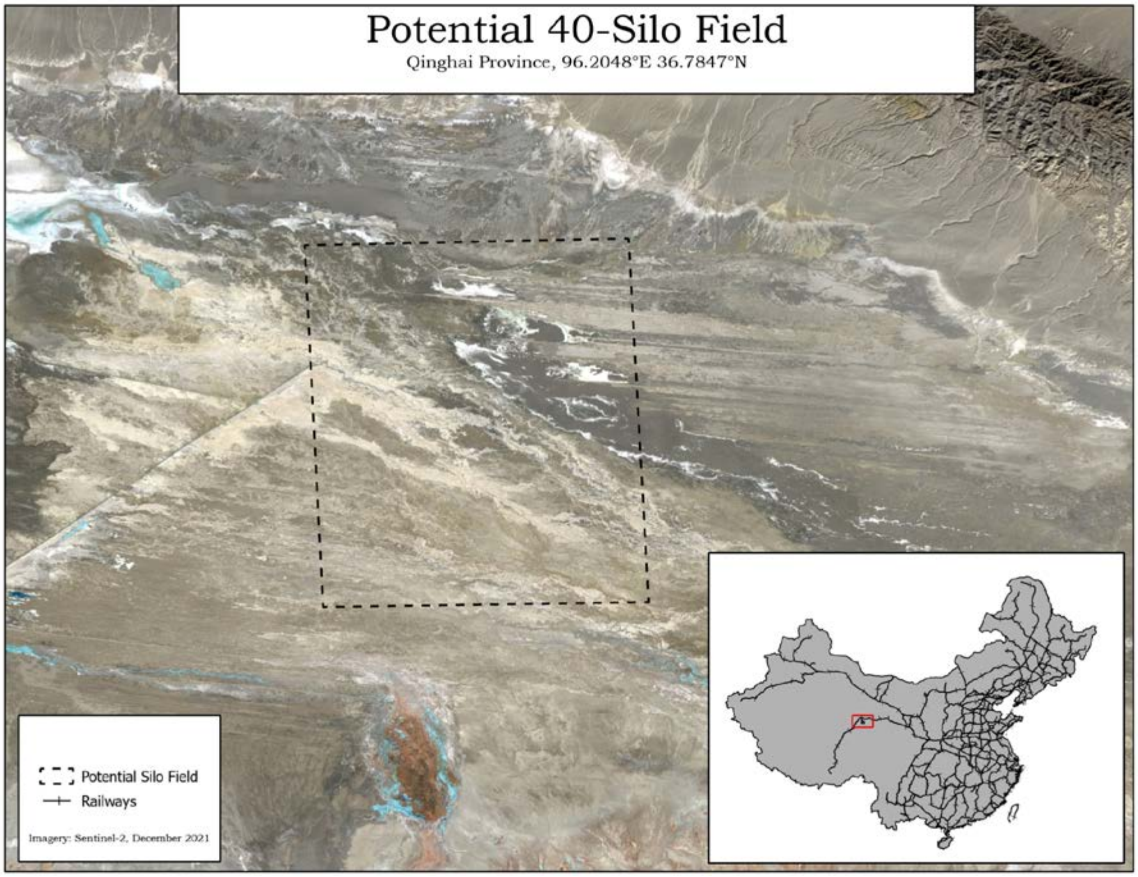
The downside of using this tool is that it arguably creates too many options for each silo field interval size. For example, the forty-silo field analysis produced over seventy-five candidate regions that met the requirements, but a large part of them were on the cusp of the twenty-five-meter depth to bedrock minimum. The intent of this report was to select the candidates that would accommodate rapid construction, so the top two options were chosen based on their bedrock depth and proximity to the railway network.

7.2 High-Level Results



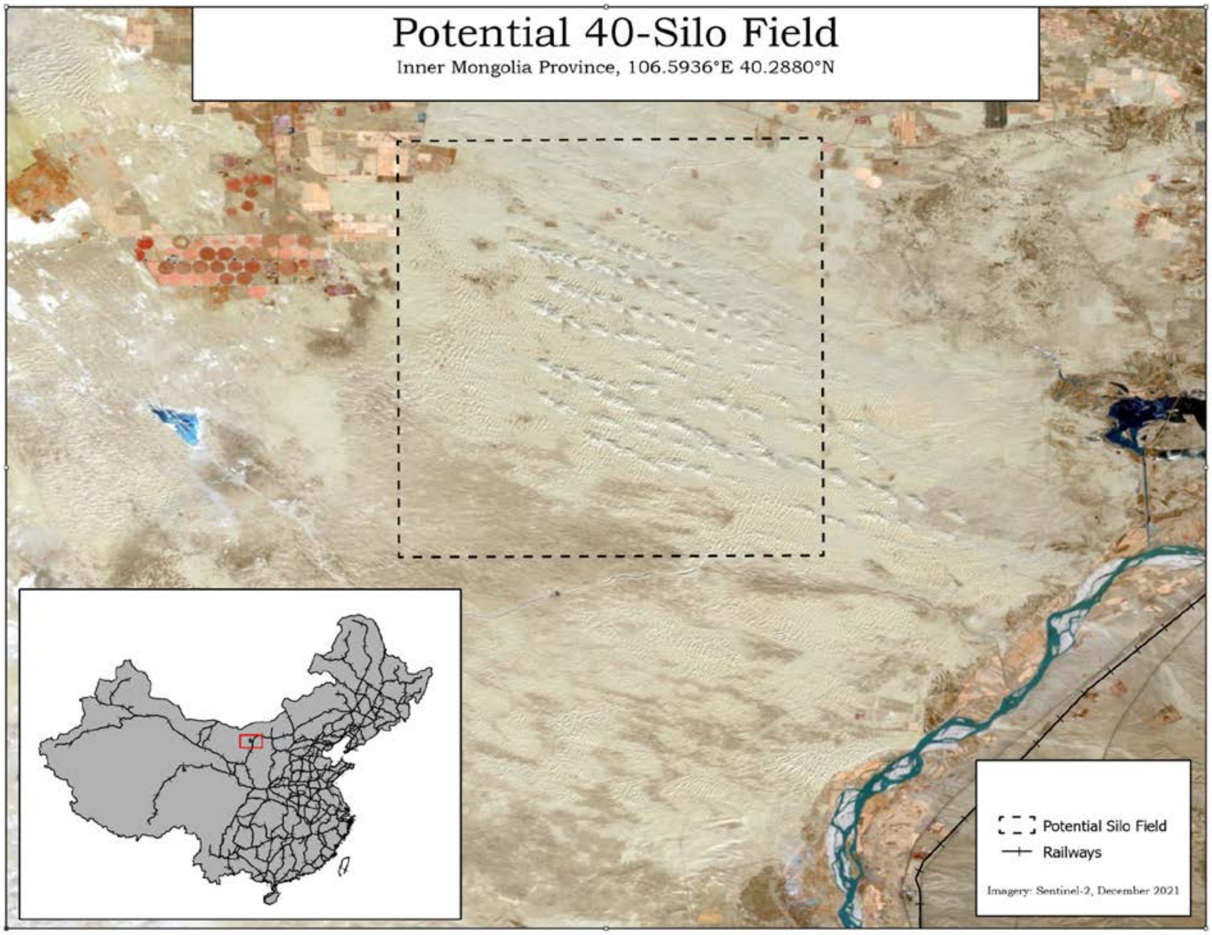
As shown in the map above, the net result of this analysis was eight candidates of varying size that are strong candidates for construction based on the heuristics covered in the Analysis Factors section. The majority of the sites are located in Western China largely because that area consists of flat bare ground, and most importantly has very deep bedrock relative to the rest of the country. It is also important to note that four of the sites are located outside of the estimated US conventional missile range which makes them even stronger candidates when including the survivability component. Each candidate is pictured below along with metrics related to each parcel's geological characteristics including average bedrock depth, average slope, land cover type, and distance to the railway network.

7.3 Forty Silo Installations



Site Number 1

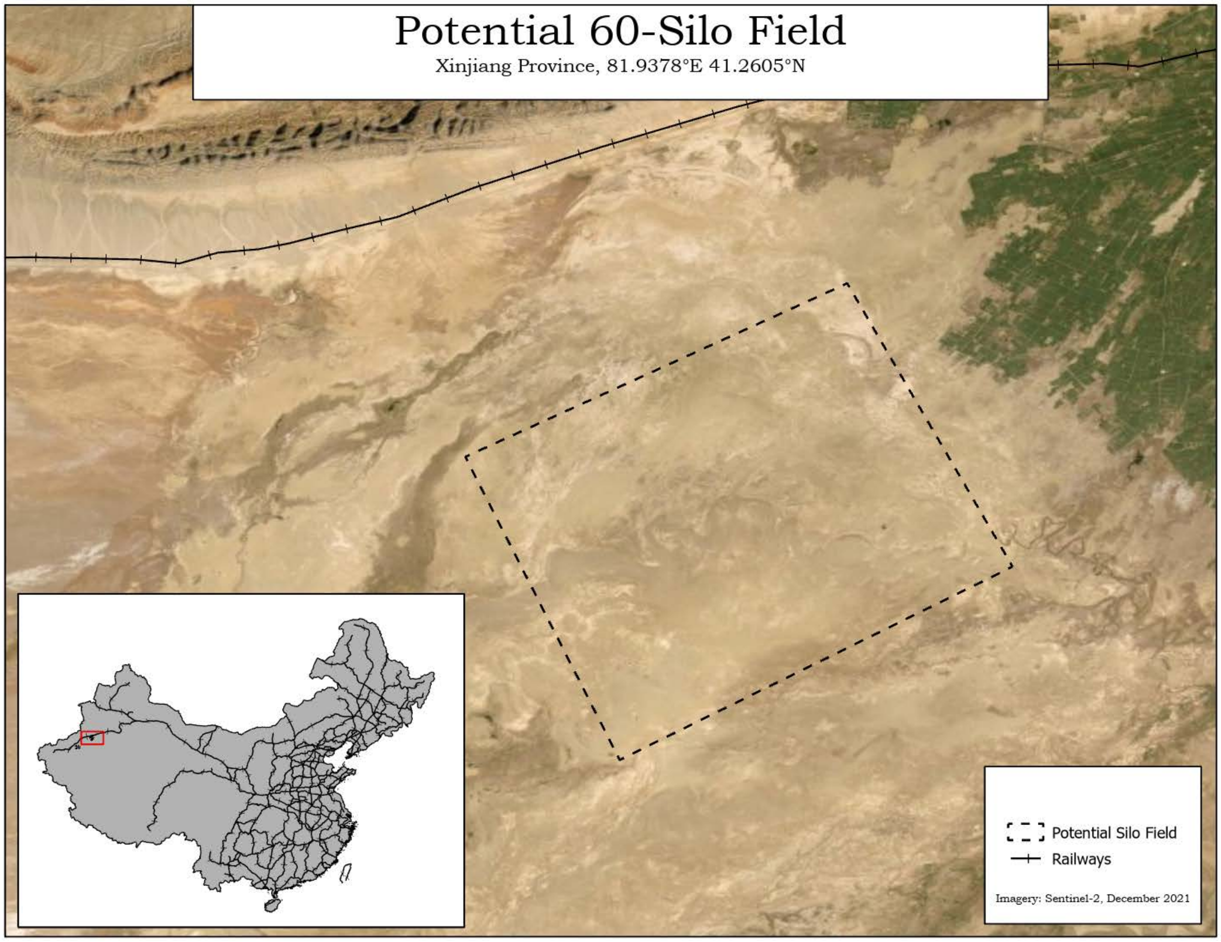
Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
40 silos	36.7847°N 96.2207°E	172.66	0.0389°	Bare Ground Shrub/Scrub	34.41 km



Site Number 2

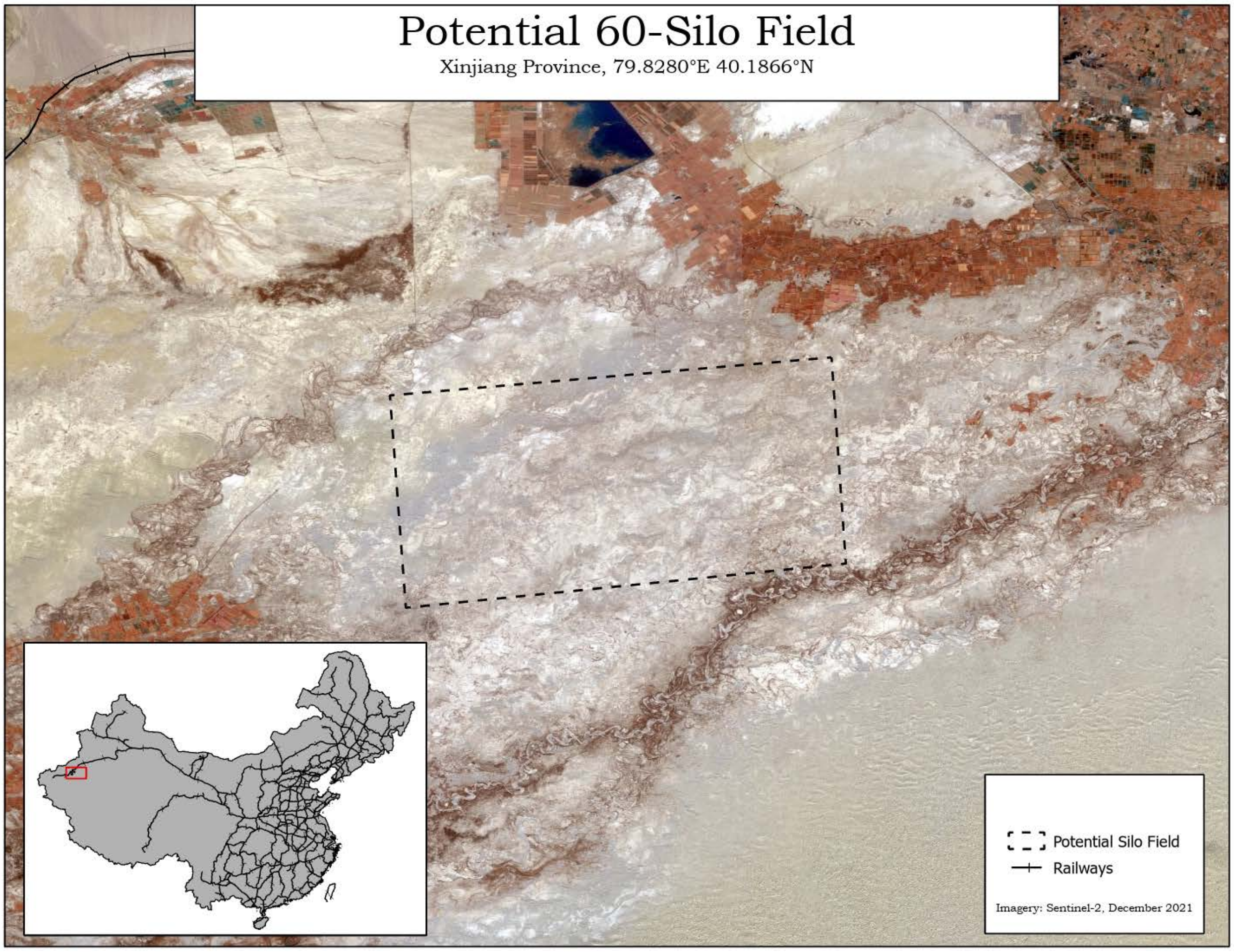
Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
40 silos	40.2886°N 106.5825°E	112.88	0.1293°	Bare Ground Shrub/Scrub	14.63 km

7.4 Sixty Silo Installations



Site Number 3

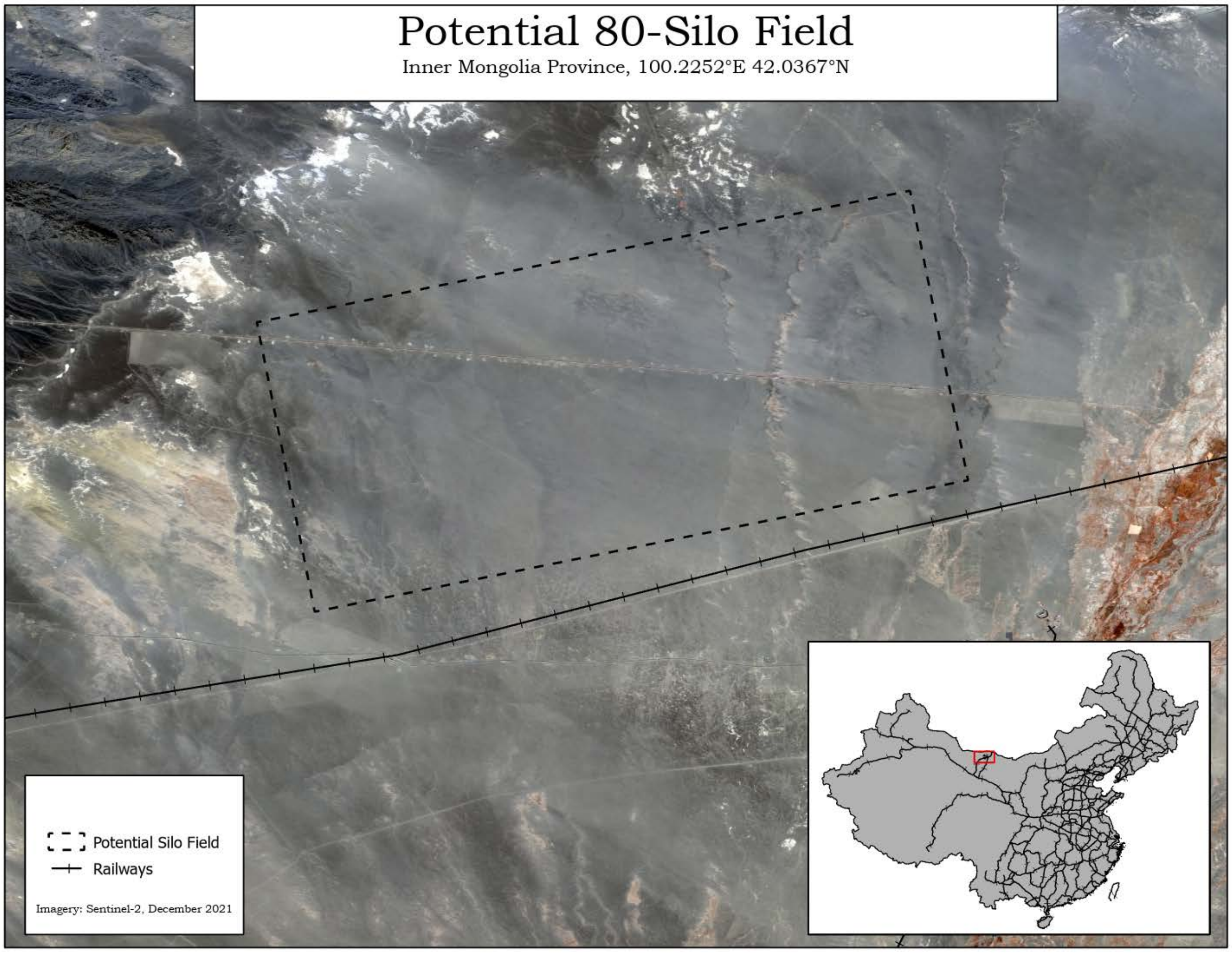
Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
60 silos	41.2256°N 82.0137°E	142.97	0.0314°	Bare Ground	15.41 km



Site Number 4

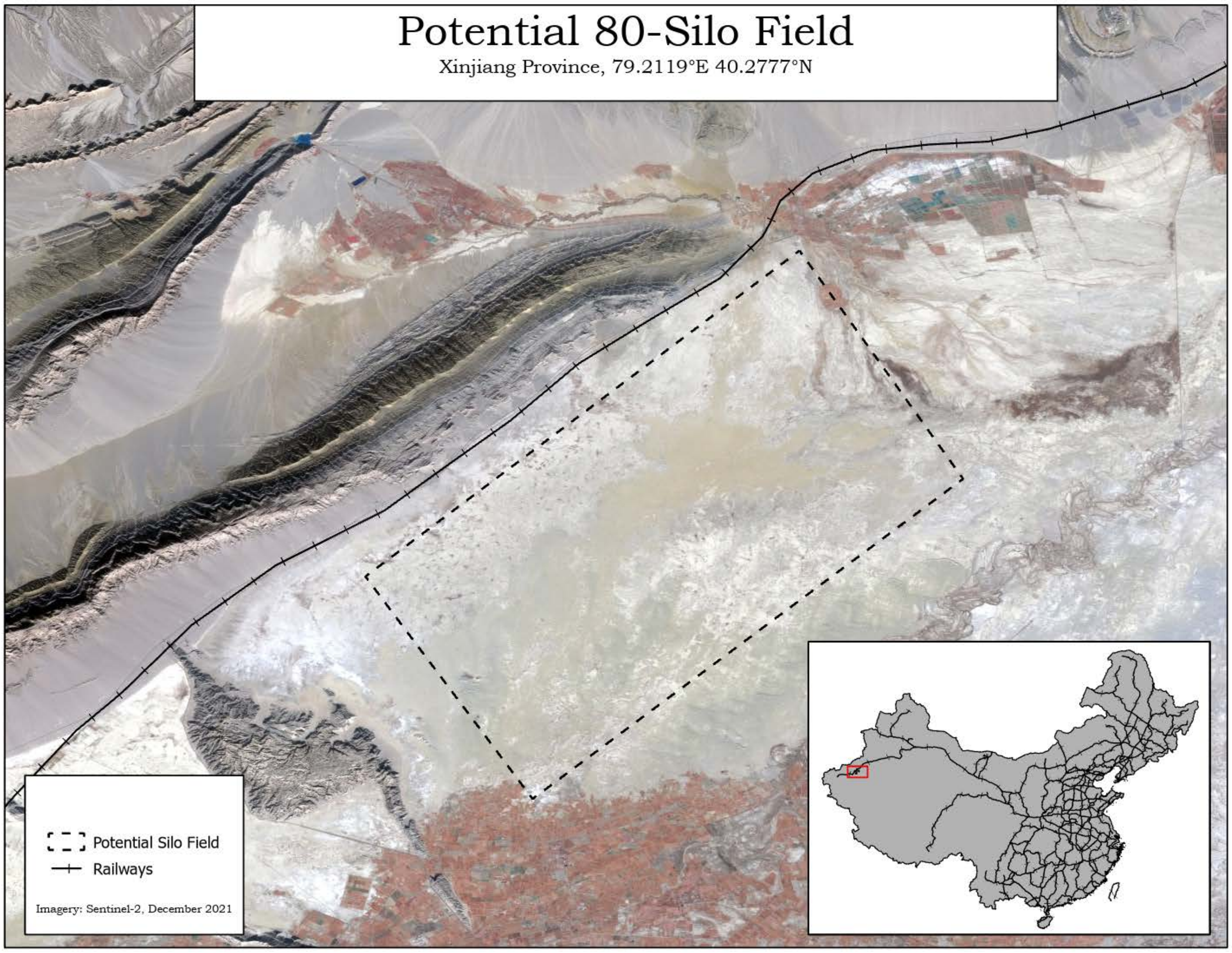
Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
60 silos	40.1825°N 79.8282°E	138.71	0.0422°	Shrub/Scrub	35.77 km

7.5 Eighty Silo Installations



Site Number 5

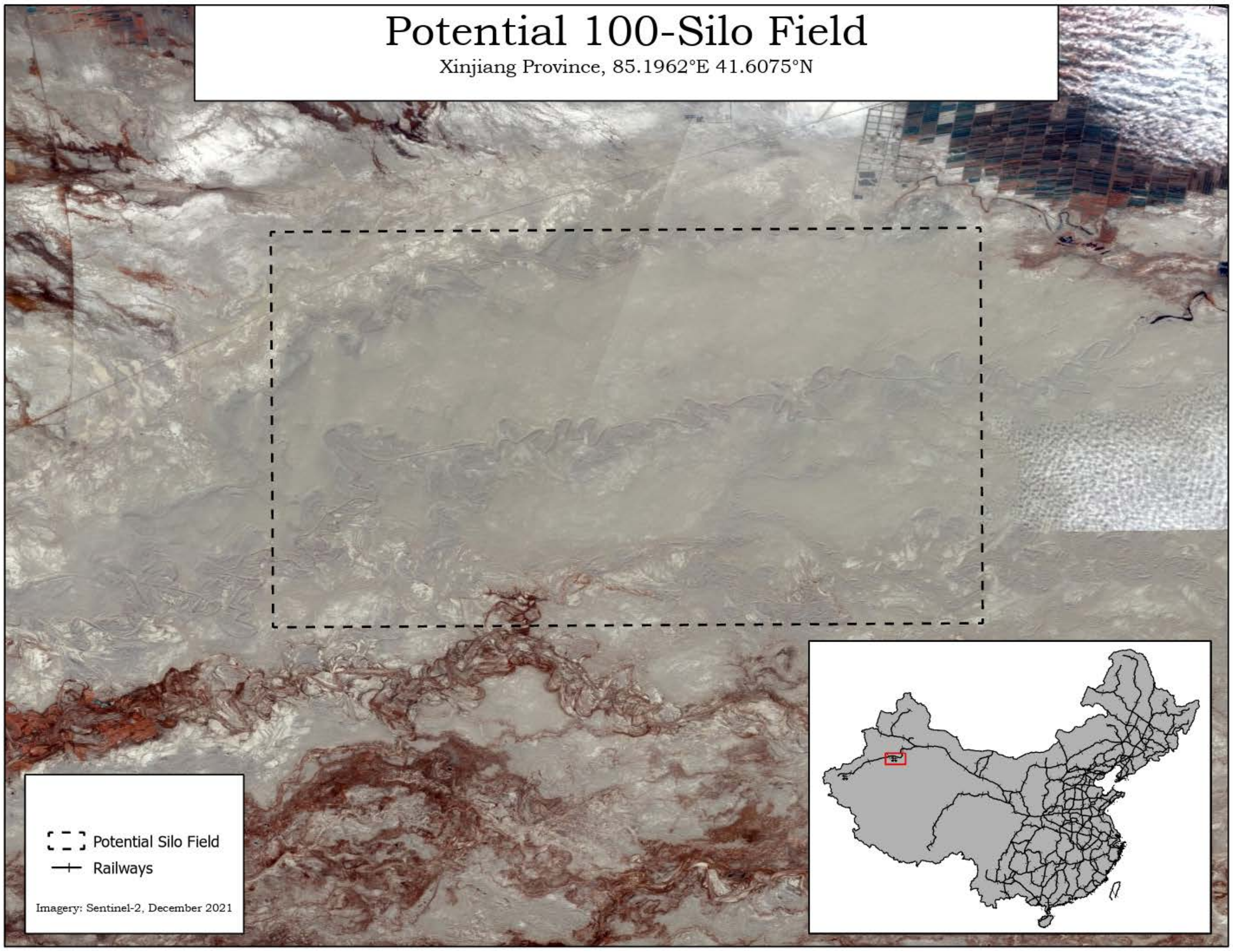
Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
80 silos	42.0613°N 100.2628°E	108.36	0.0764°	Bare Ground	3.34 km



Site Number 6

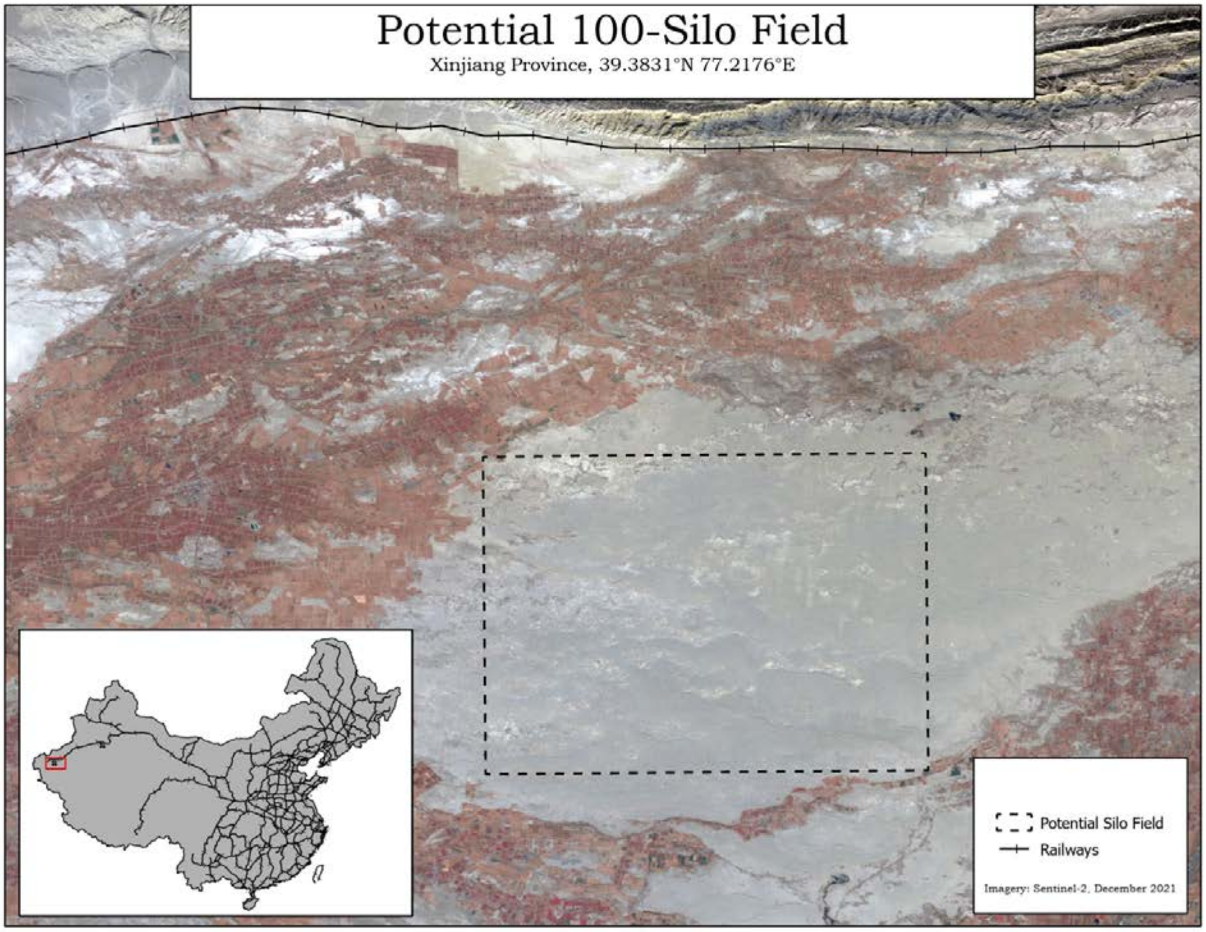
Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
80 silos	40.2620°N 79.2292°E	170.84	0.0506°	Bare Ground Shrub/Scrub	3.22 km

7.6 One-Hundred Silo Installations



Site Number 7

Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
100 silos	41.6026°N 85.2008°E	149.94	0.0449°	Bare Ground	19.89 km



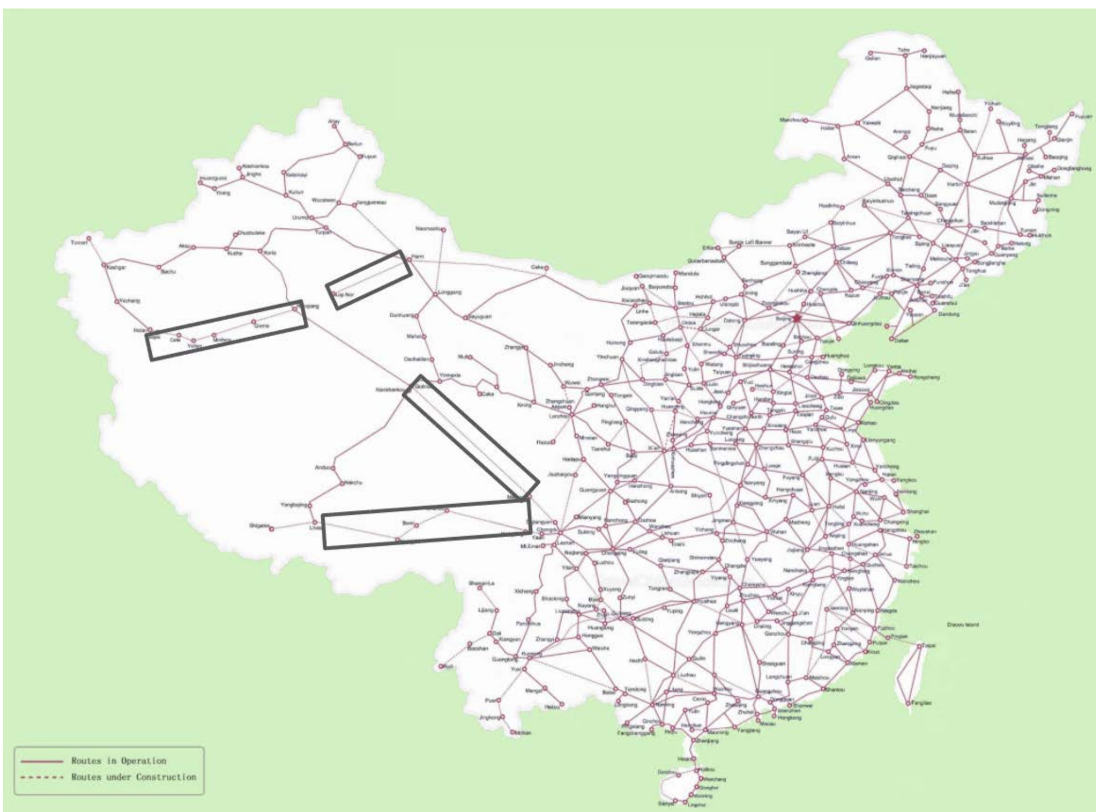
Site Number 8

Site Number	Silo Count	Coordinates	Average Bedrock Depth (m)	Average Slope (Degrees)	Land Cover Type	Distance to Railroad (km)
8	100 silos	39.3790°N 77.2201°E	187.53	0.0592°	Bare Ground Shrub/Scrub	32.34 km

8. Future Work

8.1 Shortcoming of Analysis

A large part of southwestern China that does not have a railroad in the area was ignored in this study, but depth to bedrock and the amount of bare ground makes it a strong candidate for silo construction. Several major railroad connections are under construction in the Western part of the country. The areas into which these lines are being built, combined with the favorable characteristics for silo construction in that part of the country will significantly change the calculus and make it somewhat more challenging in terms of prioritizing collection targets for discovery. It is important that open-source researchers and those in the Intelligence Community monitor the construction of these rail lines because if a new connection is discovered it could be for the PLA which could trigger a sporadic search for signs of silo construction. The graphic below points out the major rail lines that are under construction.



Railway Lines Planned/Under Construction[15]

[15] *China Railway Map*. (2021). Travel China Guide. Retrieved December 2, 2021, from https://www.travelchinaguide.com/images/map/railway.jpg.

Several months into this study there were reports indicating that the Chinese were building another silo field in Gansu Province, which was approximately 68 kilometers outside the buffer region calculated in this study. If this study were to be conducted again it would be wise to increase the buffer region to the distance of that site from the railway. This adjustment would have little to no impact on the results in Eastern China, but it would increase the amount of silo field candidates in the western part of the country.

One of the key assumptions in this report was that the Chinese would almost exclusively use their railway network instead of major roads to transport materials, the missiles themselves, and heavy construction equipment. China has a developed highway system that you would expect from a wealthy nation, but there is little to no literature on the silo construction process in China. The PLA has a road mobile version of the DF-41[16] that could transport the delivery systems to a silo field, but it is the author's position that the construction process would still depend on railroads to construct a silo installation of this size. For that reason, this study assumed that the construction process would be similar to the Soviet Union, which depended on relative distance to the railroad.

[16] Military and Security Developments Involving the People's Republic of China 2013 (PDF). *Office of the Secretary of Defense* (Report). U.S. Department of Defense. 2013. p. 6. Retrieved 02 December 2021

9. Works Cited

Hans M. Kristensen & Robert S. Norris (2011) *Chinese nuclear forces, 2011*, Bulletin of the Atomic Scientists, 67:6, 81-87, DOI: 10.1177/0096340211426630

"China Publishes White Paper on Arms Control". China.org.cn. September 1, 2005. Archived from the original on May 11, 2013. Retrieved October 15, 2013.

Gady, F.-S. (2016, January 5). *China tests new rail-mobile missile capable of hitting all of US*. – The Diplomat. Retrieved December 1, 2021, from https://thediplomat.com/2016/01/china-tests-new-rail-mobile-missile-capable-of-hitting-all-of-us/.

Korda, M., & Kristensen, H. (2021, July 26). *China Is Building A Second Nuclear Missile Silo Field*. Federation Of American Scientists. Retrieved December 1, 2021, from https://fas.org/blogs/security/2021/07/china-is-building-a-second-nuclear-missile-silo-field/.

Center for Strategic and International Studies. (2021, July 31). *DF-41 (Dong Feng-41 / CSS-X-20).* Missile Threat. Retrieved December 1, 2021, from https://missilethreat.csis.org/missile/df-41/.

Center for Strategic and International Studies. (2021, July 31). *Tomahawk*. Missile Threat. Retrieved December 1, 2021, from https://missilethreat.csis.org/missile/tomahawk/.

Barnes, J. E. (2021, October 7). *C.I.A. Reorganization to Place New Focus on China*. The New York Times. Retrieved December 1, 2021, from https://www.nytimes.com/2021/10/07/us/politics/cia-reorganization-china.html.

Kapur, S. (2017). *Stability-instability paradox*. In F. Moghaddam (Ed.), The SAGE encyclopedia of political behavior (pp. 799-801). SAGE Publications, Inc., https://www.doi.org/10.4135/9781483391144.n364

Korda, M., & Kristensen, H. (2021, November 2). *A Closer Look at China's Missile Silo Construction*. Federation Of American Scientists. Retrieved December 1, 2021, from https://fas.org/blogs/security/2021/11/a-closer-look-at-chinas-missile-silo-construction/.

Yan, F., Shangguan, W., Zhang, J. et al. Depth-to-bedrock map of China at a spatial resolution of 100 meters. Sci Data 7, 2 (2020). https://doi.org/10.1038/s41597-019-0345-6

Dorfman, Z., & Allen-Ebrahimian, B. (2020, June 24). *Defense Department produces list of Chinese military-linked companies*. Axios. Retrieved December 1, 2021, from https://www.axios.com/defense-department-chinese-military-linked-companies-856b9315-48d2-4aec-b932-97b8f29a4d40.html

Li, Yifan, 2016, "China High Speed Railways and Stations (2016)", https://doi.org/10.7910/DVN/JIISNB, Harvard Dataverse, V1

China Railway Map. (2021). Travel China Guide. Retrieved December 2, 2021, from https://www.travelchinaguide.com/images/map/railway.jpg.

Kristensen, H. (n.d.). *Chinese Missile Facilities*. Missile Facilities - China Nuclear Forces. Retrieved September 12, 2021, from https://nuke.fas.org/guide/china/facility/missile.htm

Military and Security Developments Involving the People's Republic of China 2013 (PDF). *Office of the Secretary of Defense* (Report). U.S. Department of Defense. 2013. p. 6

Korolev, A. (2020, November 19). *China–Russia cooperation on missile attack early warning systems*. Economics, Politics and Public Policy in East Asia and the Pacific. Retrieved December 2, 2021, from https://www.eastasiaforum.org/2020/11/20/china-russia-cooperation-on-missile-attack-early-warning-systems/