

Search for Possible
Millimeter Array Sites
on the U. S. Mainland

MMA Site File Report No. 6
(Supersedes File Reports No. 1 and 2)

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I. THE MAINSEARCH

Several years ago, we made a systematic map search for places on the United States mainland that are south of latitude 36°N and at least 9000 feet above mean sea level. These are absolute criteria. The choice of 36°N for the northern latitude limit was dictated by (1) the tendency for winter weather to be much more severe at high altitudes to the north of that latitude and (2) the astronomical need to keep the southern declination limit of the MMA as far south as possible. The elevation limit follows from the excessive moisture that is usually present above places at lower elevations. We require a location superior in this respect to the VLA site (7000 ft above mean sea level).

Each location that met the above primary criteria was examined in terms of the following considerations, in order to ascertain which (if any) would be viable candidates for the MMA site:

- (1) *Whether the area above 9000 feet is large enough and of the right shape to accommodate an array 3 km NS × 2 km EW.* Ideally, one would prefer a flat site that slopes just enough to be well-drained. It is more realistic to seek a site that is free of excessive slopes and other surface relief (since the antennas must be readily movable and accessible for service) and that permits astronomically efficient placement of antenna stations (even if the locations are constrained by the shape of the terrain). It is imperative to limit environmental disruption by adopting a site that can be developed with as little disturbance as possible.
- (2) *Accessibility by existing roads.* Road-building of the quality required for MMA access is likely to entail appreciable environmental disturbance. Therefore we hope to make the greatest possible use of roads that already exist, reworking them only to the extent necessary. We have rejected potential sites that would require construction of more than 3 miles of new road over anything other than benign terrain.
- (3) *Site availability.* Most land at the high elevation that we require is in the public domain, usually in National Forests and therefore in principle obtainable for scientific use. Sites in Wilderness Areas are untouchable, of course.

- (4) *Hostile activities.* Any activity near a site that might conflict with the environmental needs of the instrument is cause for rejection. Nearby radio transmitters are an obvious example. Also to be avoided are areas with significant vehicular traffic, mining, timbering, etc.
- (5) *Logistic support.* It is necessary that a community able to absorb at least 50 new families and to provide basic logistic support for the MMA be located no more than one hour driving time (good weather, dry roads) from the site. It is important that the community have schools and medical facilities adequate for the site staff and their families.

The basic maps used to find places meeting the 9000 ft elevation criterion were the old series of aeronautical sectional charts issued by the Department of Commerce prior to 1969. These served our purpose better than the more modern charts that replaced them, because they show ground elevations by more distinct color-coding and because they are less cluttered by detail that is irrelevant to us. Further examination of sites fitting the primary criteria was based on USGS topographic maps, US Forest Service maps, and state road maps.

Although there are many areas above 9000 ft MSL south of the 36th parallel, only two were judged to be suitable for MMA in the light of the above criteria. These are:

Magdalena Mountains (New Mexico), 33°56'N to 34°06'N, 107°08'W to 107°12'W. Highest point is South Baldy, 10787 ft MSL. Most of the area has been set aside as a science preserve by act of Congress. The terrain requires that the antenna stations be placed along ridge lines, but this still permits satisfactory imaging performance. All antenna stations would be near 10000 ft MSL. Road access is fairly good because of the Langmuir Laboratory, on the summit Ridge. Most of the area suitable for the MMA is in the Cibola National Forest, with some privately patented holdings on the northern side. There is no hostile activity in the area usable for the array. The site is about one hour from Socorro (population, >7000), which can provide adequate logistic support.

White Mountains (Arizona). Extensive areas above 9000 ft, 33°34'N to 34°10'N, 108°57'W to 109°43'W. The main peaks are Baldy Pk (11590 ft) and Escudilla Mt (10912 ft). The great flat expanse of open grassland that extends for several miles to the north of Big Lake is slightly above 9000 ft MSL, and includes several places that would permit the array to be built with free placement of the observing stations. There is excellent access by paved road. The best terrain for the MMA is entirely within the Apache-Sitgreaves National Forest. There is heavy recreational activity near Big Lake during the summer. The rest of the area is used for cattle grazing during the warm months. There is no hostile activity in the grassland that would be used for the array, although there is logging in the surrounding forests. Springerville and Eagar are about 30 minutes from the site by road. These communities and others within a one-hour drive of the site can provide adequate logistic support.

The Appendix lists, by aeronautical chart, sites satisfying the latitude and elevation criteria but unacceptable in view of other desiderata. Reasons for rejection are noted with each entry, using the following keys for brevity:

- A: *The array will not fit in the area above 9000 feet MSL, because either the area is too small or it is too awkwardly shaped.*
- B: *The site is in a Wilderness Area. Potential sites contiguous with designated Wilderness Areas have been included in this category as being incompatible with the primary use of the area.*
- C: *The terrain is too steep or too rugged to permit array development without excess environmental damage.*
- D: *There is no usable road within 3 miles of the site area, and construction of needed roads would involve disruption of environmentally sensitive areas.*
- E: *There is no community within 1 hour driving distance that can provide adequate support.*
- F: *Incompatible activity in the near vicinity (radio transmitters or heavy recreational use or both).*

II. SITES NORTH OF LATITUDE 36°N

In addition to the southern site possibilities, we have given some consideration to a few areas between latitudes 36°N and 40°N. These are described briefly below.

South Park, Colorado: 39°.2N, 105°.9W. Large intermontane valley, about 15 miles EW by 25 miles NS. Locally quite flat, with elevations generally between 9000 and 10000 ft MSL. Ranching country, mostly privately owned, but large tracts are held by the State of Colorado or the Federal Government (BLM). Highway distances from major centers: 90 miles from Denver via US 285, 60 miles from Colorado Springs via US 24 (road from Colorado Springs is the better of the two). The area was visually inspected by Pat Crane in 1990 and by me in 1992. There is much recreational and residential development which doubtless will continue under pressure from Denver and Colorado Springs. The bowl-like terrain is likely to trap cold air, with adverse effects on phase stability. South Park seems not to be a promising place for the MMA.

Cannibal Plateau, Colorado: 38°.1N, 107°.2W. Extensive flat-topped eminence that falls away gently to the south, steeply in other directions. The name is said to celebrate the non-nonsense survival technique of 19th century prospector Alf Packer, who lived through a harsh winter that his companions did not. In the Gunnison National Forest. Highest point is at 12522 ft MSL. The flattest part, with slopes mostly less than 2°, extends about 2 miles EW and 4 miles NS. Near the tree line (about 12000 ft MSL). Far from any existing road; the closest possible connection with a paved highway is 15 miles south (onto CO

149). The nearest town is Lake City (pop. <200), which in turn is 56 miles south of Gunnison (pop. 5800) via US 50 and CO 149. The shortest feasible road distance from Lake City to the site would be about 40 miles. The area is too inaccessible to merit serious consideration, although it is the highest we have noted, and the most charmingly named. We have not visited it.

Grand Mesa, Colorado: 39°.0N, 108°.2W. In the Grand Mesa National Forest. Extensive area near 10000 ft MSL. Excellent accessibility via paved roads. Conveniently near a major town (Grand Junction, pop. 28100). Heavy recreational use. There are a number of radio towers at the west end of the mesa, overlooking Grand Junction, that might cause unacceptable RFI levels. The recreational popularity of the area could ensure strong public opposition to use by the MMA.

Aquarius Plateau, Utah: 38°.1N, 111°.5W. In the Dixie National Forest. Highest point is Blue Bell knoll, 11328 ft MSL. The area above 11000 ft MSL is roughly 8 miles in diameter, flat but poorly drained, with numerous small intermittent lakes. Local Forest Service personnel report that snow depths are sometimes as much as 20 feet. Fairly easy access by Forest Service road except in winter. The climate is subarctic. A party from NRAO experienced snow in the summit area on 1 June 1984. Road distance to the village of Bicknell, the nearest settlement, is about 25 miles. Support would be very tough with this site. The only town within 100 miles by road that has a population of more than 5000 is Richfield (1980 population, 5482; road distance, 80 miles).

Osier Mesa, New Mexico: 36°.9N, 106°.4W. In the Carson National Forest. Highest point is an unnamed knoll at 10745 ft MSL. Familiar to several members of the NRAO staff who do cross-country skiing in the area. They report that the terrain looks quite suitable for the MMA and that persistent heavy snow would make winter operation difficult. The area is quite isolated. Chama (population, 1000) is no more than an hour away by road, but it does not have the resources to support the MMA. The nearest towns that could support the facility, Pagosa Springs (1980 population, 7079) and Alamosa (1980 population, 6830), are in Colorado, and each is about 70 miles by road from the site. Winter travel from either of these towns to the site often would be difficult.

Sage Hen Flat (White Mountains), California: 37°.5N, 118°.2W. In the Ancient Bristlecone Pine Forest, a separate administrative unit within the Inyo National Forest. Typical elevation is around 10500 ft MSL. Road distance from Bishop (population 3700) is about 44 miles. The area is not suitable for the MMA for a number of reasons, the most important being: (1) the flat portion is not wide enough in the NS direction, because of surrounding mountains and canyons; (2) the Forest Service permits no new non-interpretive development within the Ancient Bristlecone Pine Forest; (3) winter access and operation would be difficult owing to high snowfall. See MMA Site File Report No. 3 (September 1992).

APPENDIX: Rejected sites south of 36°N latitude.
See page 3 for explanation of rejection keys

ALBUQUERQUE 1:500,000
 [34°N - 36°N, 102°W - 108°W]

Location	Land Status
Sangre de Cristo Mts, 35°35'N to 36°00'N, 105°22'W to 105°52'W. Highest point is Truchas Pk, 13102 ft MSL. Area is rugged and generally inaccessible. Rejection keys: B, D, E	Santa Fe NF, Pecos WA
Jemez Mts, 35°43'N to 36°00'N, in 106°18'W to 106°42'W. Ridges and cones along rim and ring faults of caldera. Highest point is Redondo Pk, 11254 ft MSL. Close to Los Alamos. Good road access to much of the area. Rejection keys: A, C	Santa Fe NF, Baca Location No. 1
Manzano Mts, 34°34'N to 34°49'N, long. 106°24'W to 106°28'W. Long ridge, parts of which are above 9000 ft. Highest point is Manzano Pk, 10098 ft MSL. Mostly inaccessible, but there is a road to the Capilla Peak Observatory (UNM) at 9324 ft MSL. Rejection keys: B, C, D, E, F	Cibola NF, Manzano Mtns WA
Sandía Mts, 35°06'N to 35°16'N, 105°24'W to 105°28'W. Ridge; highest point is Sandia Crest, 10852 ft MSL. Ski area is accessible from west by tramway and from east by paved road. Close to Albuquerque. Many transmitters on the crest, hence the RFI environment must be poor. Rejection keys: A, B, C, F	Cibola NF Sandia Mtn WA
Sierra Nacimiento, 35°46'N to 35°59'N, 106°48'W to 106°53'W. Ridge, parts of which are over 9000 ft. Highest point is 9470 ft MSL. Generally inaccessible. Rejection keys: A, C, D, E	Santa Fe NF
Mt. Taylor, 35°11'N to 35°18'N, 107°32'W to 107°40'W. Summit at 11301 ft MSL. Road goes nearly to the top. The mean slope above 9000 ft is 12%, which is high but not necessarily impossible for array purposes. The terrain, however, is extremely rough. Rejection key: C	Cibola NF
Datil Mts, 34°15'N to 34°20'N, 107°52'W to 107°58'W. Highest point is Madre Mt., 9560 ft MSL. Near Datil. MCI repeater station may cause RFI. Rejection keys: A, C, D, E, F	Cibola NF
Crosby Mt, 34°06'N to 34°10'N, 107°56'W to 107°58'W. Summit is 9460 ft MSL. Near Datil. Rejection keys: A, C, E	Cibola NF
Sierra Ladrones, 34°26'N, 107°05'W, summit 9176 ft MSL. Area above 9000 ft is small, and the terrain is very rough. Rejection keys: A, C, D, E	

PRESCOTT 1:500,000
[34°N - 36°N, 108°W - 114°W]

Location	Land Status
Three summits in 35°07'N to 35°11'N, 108°05'W to 108°18'W are above 9000 ft. Between Gallup and Grants. All are much too small. Rejection key: A	
Alegros Mt, 34°09'N, 108°11'W, summit 10244 ft MSL. Narrow ridge with steep sides. Rejection keys: A, C, D, E	State of NM
Several small areas in the Mangas and Gallo Mts, 34°01'N to 34°12'N, 108°15'W to 108°43'W, lie above 9000 ft. The highest is 9869 ft MSL. The area above 9000 ft around Mangas Mt (34°03'N, 108°18'W, 9650 ft MSL) is 2 - 3 miles across, but too rough for the array. There is a dirt road to the summit area which facilitates service of the WNM telephone repeater on top (a source of RFI?). The other high spots in this group are too small for the array. Rejection keys: A, C, E, F	Apache NF
Southern Chuska Mts, 35°56'N to 36°00'N, 108°46'W to 108°52'W. Ridge, some parts of which are over 9000 ft, but all such are too small for the array. Rejection keys: A, C, D, E	
Areas north and west of Flagstaff are above 9000 ft, but very steep. 35°14'N to 35°25'N, 111°42'W to 112°13'W. Highest point is Humphreys Pk, 12635 ft MSL, which lacks road access. Others, all too small, are: Kendrick Pk, 10418 ft; Sitgreaves Mtn, 9388 ft; Bill Williams Mtn, 9256 ft. Rejection keys: C, D	Coconino NF

LOS ANGELES 1:500,000
[34°N - 36°N, 114°W - 120°W]

Location	Land Status
San Bernardino Mts, 34°03'N to 34°12'N, 116°43'W to 116°52'W. Highest point is Mt. San Gorgonio, 11502 ft MSL. Rejection keys: B, C, D	San Bernardino NF, San Gorgonio WA
San Gabriel Mts, 34°16'N to 34°22'N, 117°36'W to 117°48'W. Highest point is Mt. San Antonio, 10064 ft MSL. Adjacent to San Gabriel and Cucamonga WA's. Rejection keys: A, C	Los Angeles NF
Southern Sierra Nevada, 35°51'N to 36°00'N, 118°16'W to 118°24'W. Highest spot is Sirretta Pk, 9977 ft MSL. Adjacent to Dome Land WA. Rejection keys: A, C, E	

ROSWELL 1:500,000
[32°N - 34°N, 102°W - 108°W]

Location	Land Status
<p>Capitan Mts, 33°35'N to 33°38'N, 105°14'W to 105°26'W. Long ridge; the highest point is 10230 ft MSL.</p> <p>Rejection keys: A, C, D, E</p>	Lincoln NF
<p>Sacramento Mts, 32°43'N to 33°00'N, 105°40'W to 105°50'W. Highest point is 9686 ft MSL. Includes Sacramento Peak Observatory. Excellent access by paved road.</p> <p>Rejection keys: A, C</p>	Lincoln NF
<p>Carrizo Pk, 33°41'N, 105°44'W, summit 9656 ft MSL. The area above 9000 ft is about a mile across, with another small patch a mile to the east. Near Carrizozo and White Oaks.</p> <p>Rejection keys: A, C, E</p>	Lincoln NF
<p>Sierra Blanca - Nogal Peak area, 33°18'N to 33°31'N, 105°43'W to 105°51'W. Summits of Sierra Blanca and Nogal Pk are at 12003 and 9957 ft MSL, respectively. Good road access to 9000 ft level on Sierra Blanca because of ski area. Adjacent to White Mountain WA.</p> <p>Rejection keys: B, C, F</p>	Mescalero Apache IR, Lincoln NF
<p>Organ Needle, 32°21'N, 106°34'W, summit 9012 ft MSL. Isolated spike with no room for any instrument larger than binoculars.</p> <p>Rejection keys: A, C, E</p>	White Sands MR
<p>Northern San Mateo Mts, 33°47'N to 33°55'N, 107°26'W to 107°31'W. Highest point is Mt Withington, 10116 ft MSL. Fire tower at summit, hence good road access.</p> <p>Rejection keys: A, C, E</p>	Cibola NF
<p>Southern San Mateo Mts, 33°32'N to 33°41'N, 107°23'W to 107°28'W. Highest point is 10325 ft MSL. Remote and inaccessible.</p> <p>Rejection keys: B, D, E</p>	Cibola NF, Apache Kid WA
<p>Black Range, 32°51'N to 33°17'N, 107°46'W to 107°55'W. Highest point is 10165 ft MSL. State Highway 90 crosses the southern portion.</p> <p>Rejection keys: B, C, D, E</p>	Gila NF, Black Range PA
<p>Luera Pk, 33°49'N, 107°53'W, summit at 9455 ft MSL. Broadly rounded shield volcano. Area above 9000 ft is less than a mile across. Near VLA but quite inaccessible.</p> <p>Rejection keys: A, D, E</p>	State of NM

PHOENIX 1:500,000
[32°N - 34°N, 108°W - 114°W]

Location	Land Status																												
<p>There are numerous peaks over 9000 ft in the mountains around the western end of the Plains of San Agustin. The region is generally rugged and difficult of access. The main peaks are:</p> <table style="margin-left: 40px;"> <tr> <td>Horse Mt.</td> <td>33°59'N</td> <td>108°07'W</td> <td>9490 ft MSL</td> </tr> <tr> <td>-----</td> <td>33°45'N</td> <td>108°26'W</td> <td>9415 " "</td> </tr> <tr> <td>Eagle Pk</td> <td>33°41'N</td> <td>108°35'W</td> <td>9802 " "</td> </tr> <tr> <td>Elk Mt</td> <td>33°34'N</td> <td>108°25'W</td> <td>9799 " "</td> </tr> <tr> <td>-----</td> <td>33°36'N</td> <td>108°19'W</td> <td>9410 " "</td> </tr> <tr> <td>Black Mt</td> <td>33°23'N</td> <td>108°13'W</td> <td>9303 " "</td> </tr> <tr> <td>Pelona Mt</td> <td>33°41'N</td> <td>108°07'W</td> <td>9220 " "</td> </tr> </table> <p>The area above 9000 ft is small in all cases.</p> <p>Rejection keys: A, D, E</p>	Horse Mt.	33°59'N	108°07'W	9490 ft MSL	-----	33°45'N	108°26'W	9415 " "	Eagle Pk	33°41'N	108°35'W	9802 " "	Elk Mt	33°34'N	108°25'W	9799 " "	-----	33°36'N	108°19'W	9410 " "	Black Mt	33°23'N	108°13'W	9303 " "	Pelona Mt	33°41'N	108°07'W	9220 " "	Gila NF, State of NM
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Pelona Mt	33°41'N	108°07'W	9220 " "																										
<p>Black Pk, 32°54'N, 108°10'W, 9025 ft MSL. Area above 9000 ft is very small.</p> <p>Rejection keys: A, B, D, E</p>	Gila NF, Gila WA																												
<p>Mogollon Mts, 33°14'N to 33°31'N, 108°33'W to 108°48'W. The highest points are Whitewater Baldy (10892 ft), Mogollon Pk (10778 ft), and Bearwallow Mt (9953 ft). Rugged, difficult area.</p> <p>Rejection keys: B, C, D, E</p>	Gila WA																												
<p>Pinaleno Mts, 32°38'N to 32°44'N, 109°50'W to 109°58'W. The highest point is Mt Graham, 10713 ft MSL. Excellent road access from Safford. Serious environmental concerns.</p> <p>Rejection keys: A, C</p>	Coronado NF																												
<p>Mt Lemmon, 32°27'N, 110°47'W, summit 9157 ft MSL. Area above 9000 ft is very small. Superbly accessible from Tucson. Numerous transmitters. Heavy recreational use.</p> <p>Rejection keys: A, F</p>	Coronado NF																												

SAN DIEGO 1:500,000
[32°N - 34°N, 114°W - 120°W]

Location	Land Status
<p>San Jacinto Mts, 33°47'N to 33°50'N, 116°39'W to 116°42'W. Highest point is San Jacinto Pk, 10804 ft MSL. Area is heavily used for recreation. Accessible by cable car from Palm Springs. Closely adjacent to WA on north and south.</p> <p>Rejection keys: C, D, F</p>	San Bernardino NF, San Jacinto WA

DOUGLAS 1:500,000
 [30°N - 32°N, 108°W - 114°W]

Location	Land Status
Chiricahua Mts, 31°49'N to 31°55'N, 109°15'W to 109°19'W. Highest points are Chiricahua Pk (9796 ft) and Flys Pk (9666 ft). Very rugged area. Rejection keys: C, D	Coronado NF, Chiricahua WA
Miller Pk, 31°24'N, 110°18'W, summit 9466 ft MSL. Two small areas above 9000 ft. Rejection keys: A, C, D	Coronado NF
Mt Wrightson, 31°42'N, 110°51'W, summit 9453 ft MSL. About 2 miles east of Mt Hopkins, but not readily accessible. Rejection keys: A, C, D	Coronado NF

ABBREVIATIONS:

- NF = National Forest
- WA = Wilderness Area
- PA = Primitive Area
- IR = Indian Reservation
- MR = Missile Range