MARS CONSTELLATION DESIGN

COLORADO CENTER FOR ASTRODYNAMICS RESEARCH

FINAL REPORT
JPL CONTRACT #1214587
"MARS NETWORK NAVIGATION"

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Final Report
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In this study, several different Mars constellation designs were evaluated. Various figures of merit were used to examine constellation configurations in order to optimize the performance of Mars Network. Plots were also obtained in order to make a clear comparison of the various figures of merit.

In the following analysis, six figures of merit were used in the comparison (average time to achieve a 1 meter fix, maximum time to achieve a 1 meter fix, maximum wait time between satellite sightings, percent of time a satellite is in view, percent of cases to achieve a 1 meter fix in 10 minutes, and percent of cases to achieve a 1 meter fix in 1 hour). For the communication figures of merit (maximum wait time between satellite sightings and percent of time a satellite is in view), an initial run over a period of 10 days was used to produce the data. For the remaining figures of merit, the simulation was first restarted at least 100 times over a period of 1000 Earth days. Each time the simulation was continued until a 1 meter fix was achieved at all stations. The ground station grid was spaced 20 degrees in longitude and 5 degrees in latitude. In order to obtain the following graphs the values were first averaged over longitude and then an average of the positive and negative latitude values was made (i.e. -90° lat and 90° lat were averaged). In each case, the resulting figures of merit are shown. For some cases, the difference between the given case and the "Eagles 2 Satellites" case is also given.

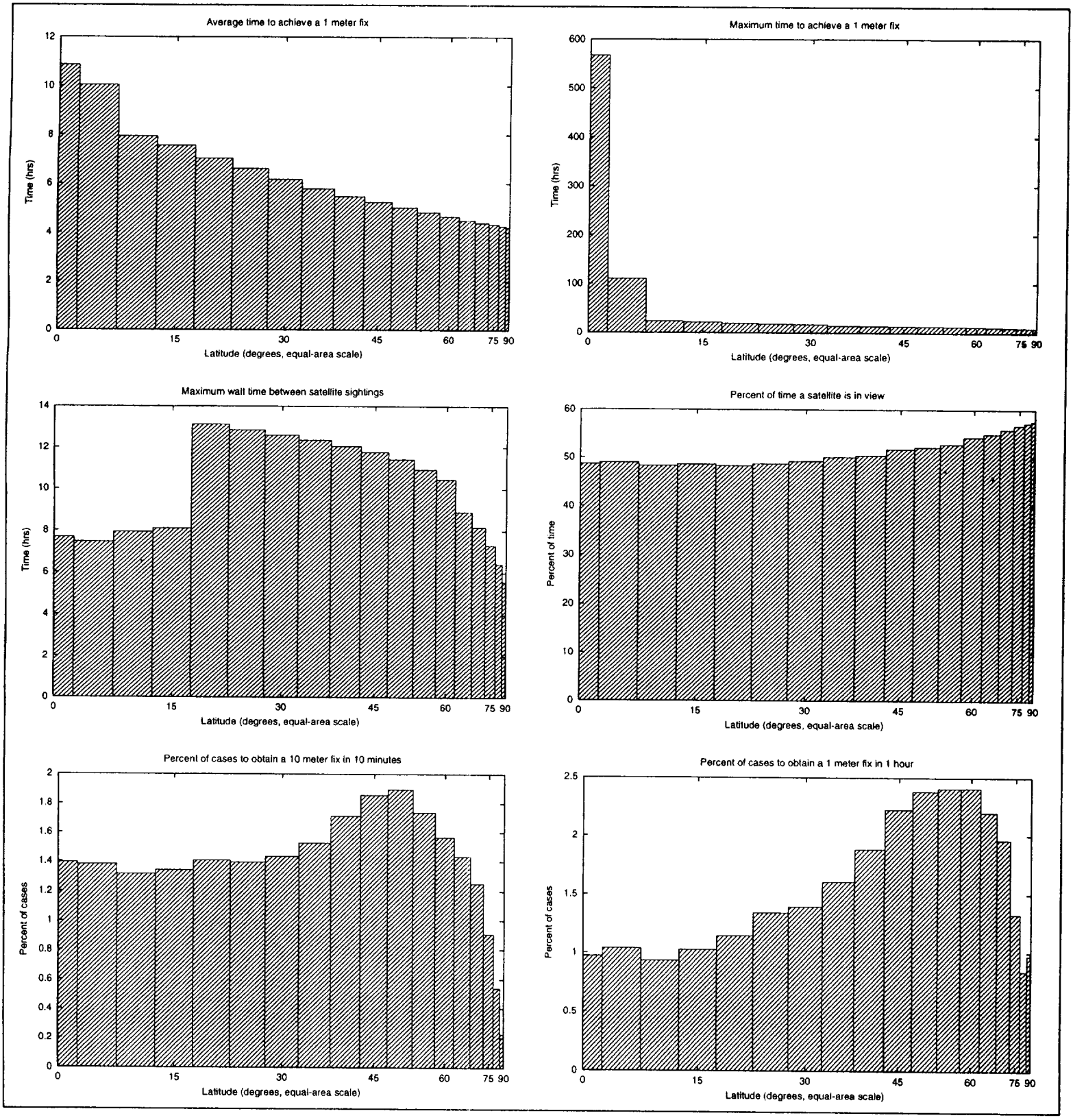
Once the figures of merit were developed, a series of constellation configurations were evaluated. Initially, the results from the six-satellite constellation were reproduced for comparison with the current configurations. The remainder of the study focused on evaluating a series of two-satellite constellations. A proposed constellation having two satellites with periapsis altitudes of 400 km, apoapsis altitudes of 18505.6 km, and inclinations of 98° was then used. It possessed poor navigation performance near the equator, but the percent of time that a satellite was in view was generally above 50 percent for all latitudes. A script was then developed to perform a search over apoapse altitude and inclination for an optimum constellation. Contour plots were used to evaluate the results, and a new constellation was selected primarily based on navigation metrics. A new constellation was chosen that significantly improved the navigation metrics near the equator, and the average time to obtain a 1-meter fixed was reduced at all latitudes. This came at the expense of the percent of time that a satellite was in view. The final configuration could be selected based on the relative importance of the navigation and communication figures of merit. For the navigation figures of merit, the final simulation was restarted 200 times over a period of 10,000 Earth days rather than 1000 Earth days. The time period for the communication figures of merit was increased to 15 days from 10 days. These changes were made to account for the fact that the orbits used in this study precessed much more slowly than those used in the six-satellite constellations.

In this study, several figures of merit were developed that produced a measure of the performance of a given constellation. The results were used to produce a constellation that improved navigation performance relative to the originally proposed

constellation, and to show the trades between navigation and communication performance. A constellation configuration with an increased inclination and reduced apoapsis altitude was found to produce improved navigation results at the expense of degradation in communication metrics. The final constellation improved the navigation performance without significantly degrading the communication metrics. Plots of the various figures of merit for the most interesting cases are given next.

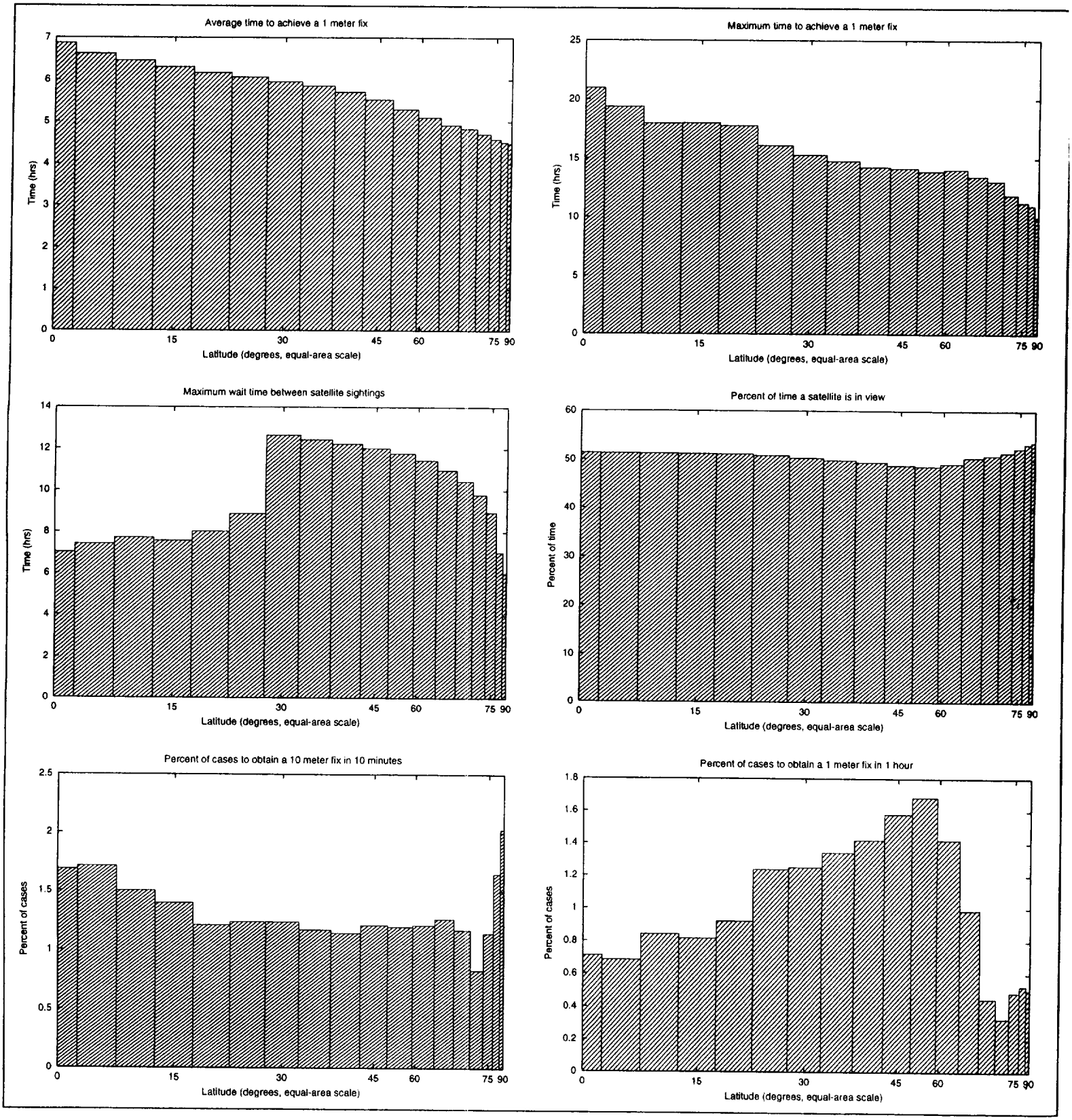
Eagles – 2 Satellites

Satellite #	alt_p (km)	alt_a (km)	inc (deg)	Ω (deg)	ω (deg)	M (deg)
1	400	18505.6	98	0	155	0
2	400	18505.6	98	0	335	0
Maximum wait (over 15 days): 787.2 minutes						



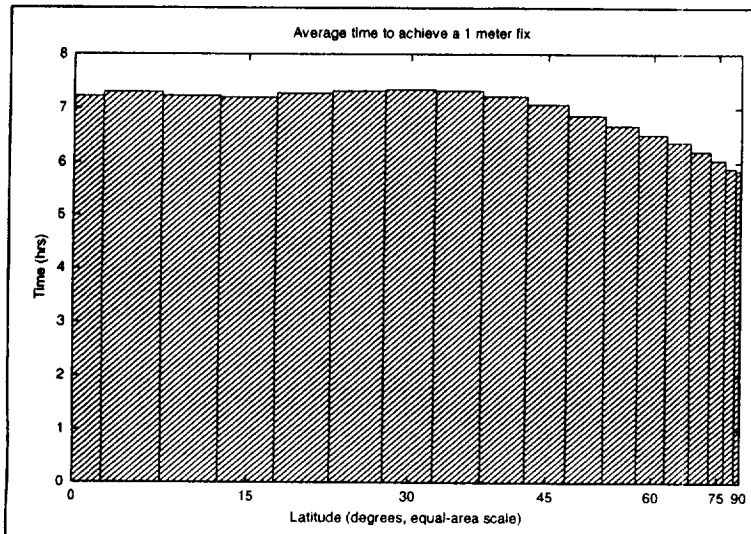
Eccentric (A)

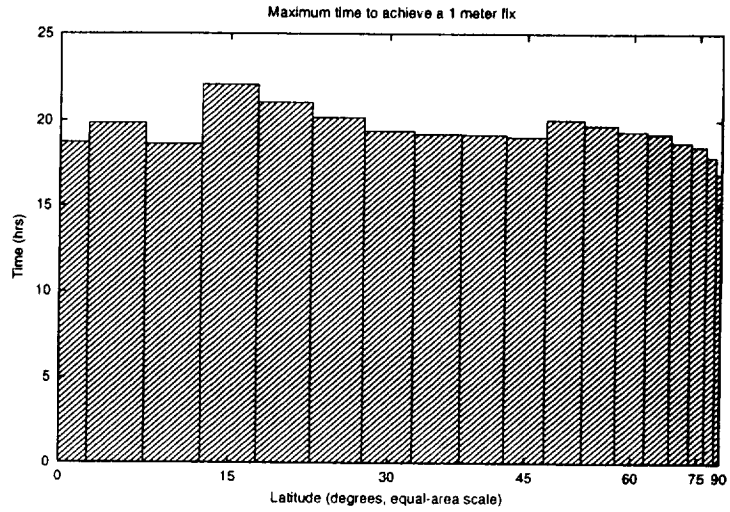
Satellite #	alt_p (km)	alt_a (km)	inc (deg)	Ω (deg)	ω (deg)	M (deg)
1	400	18505.6	111	0	155	0
2	400	18505.6	111	0	335	0
Maximum wait (over 15 days): 759.0 minutes						

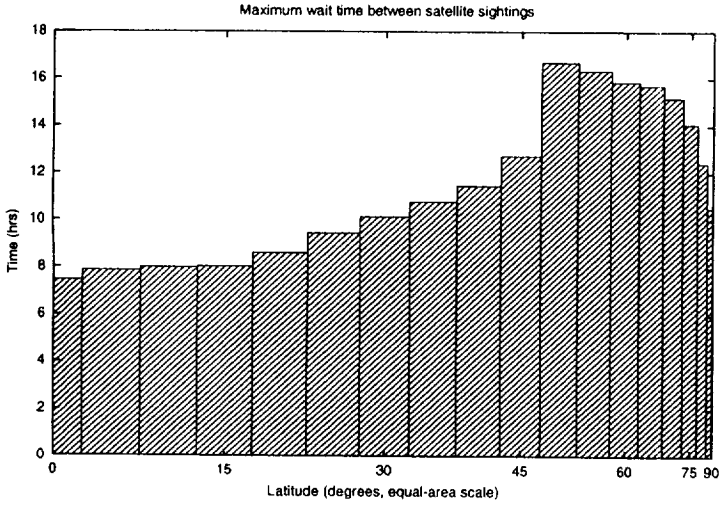


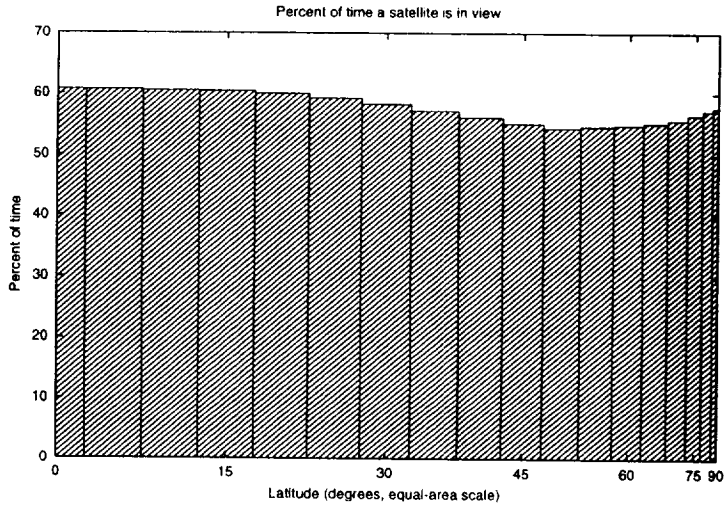
Eccentric (B)

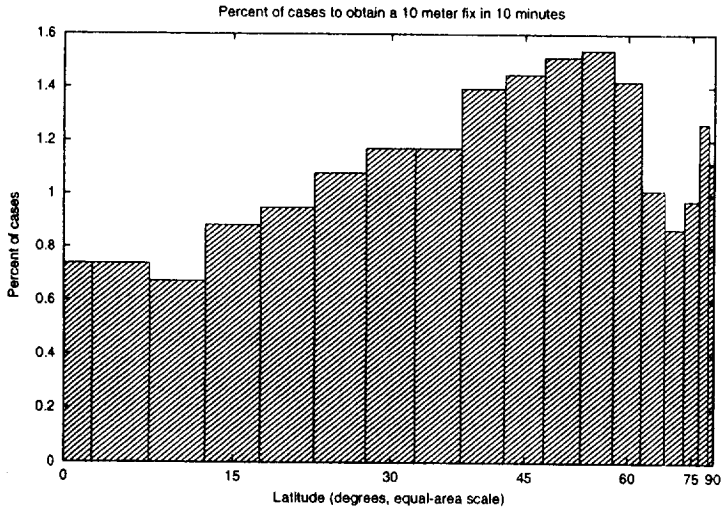
Satellite #	alt_p (km)	alt_a (km)	inc (deg)	Ω (deg)	ω (deg)	M (deg)
1	400	30000	111	0	335	0
2	400	30000	111	0	155	0
Maximum wait (over 15 days): 1000.2 minutes						

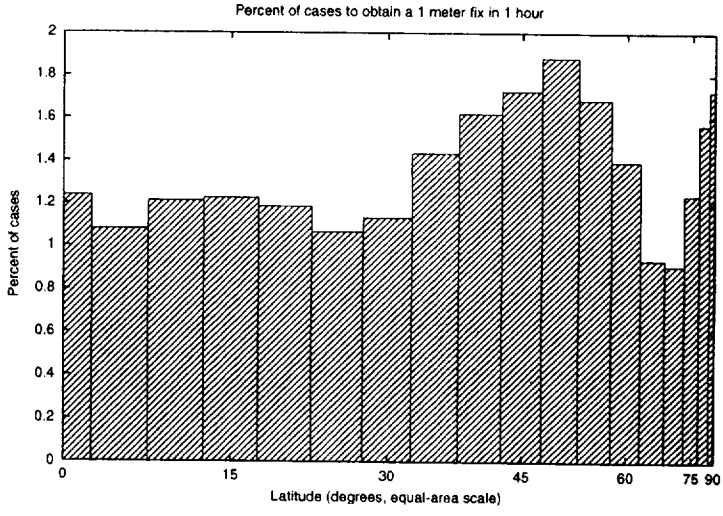




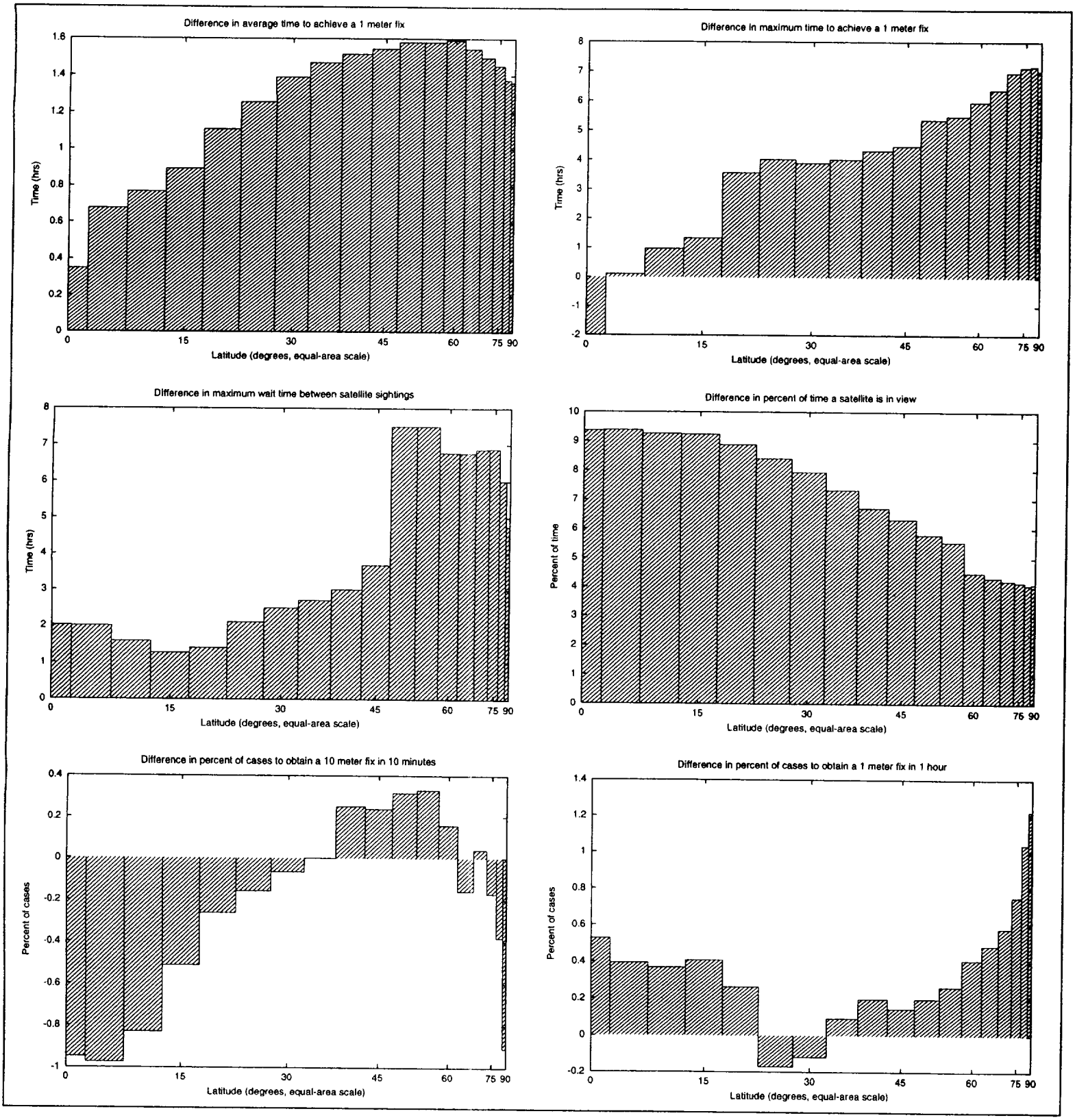






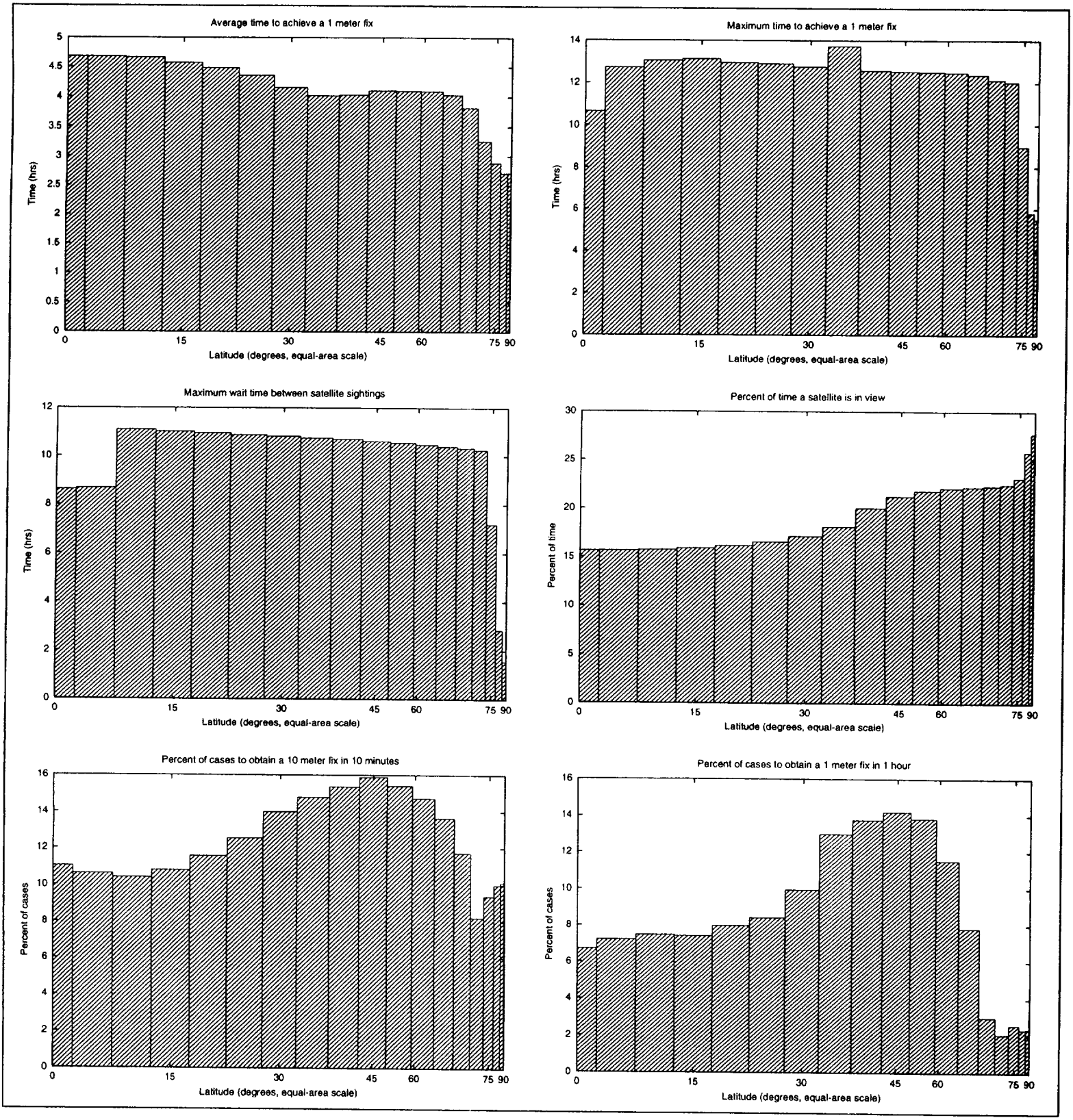


[Eccentric (B)] - [Eccentric (A)]

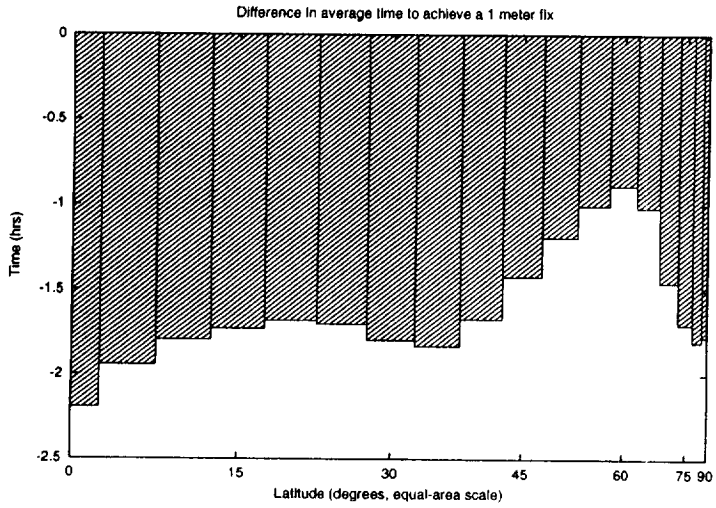


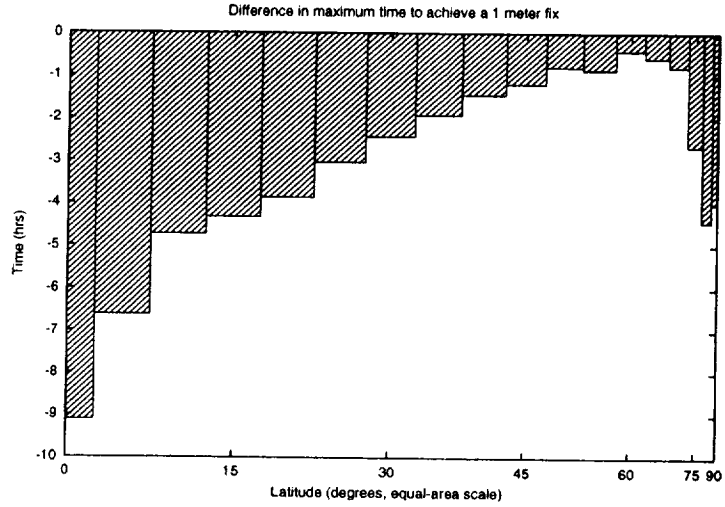
Eccentric C

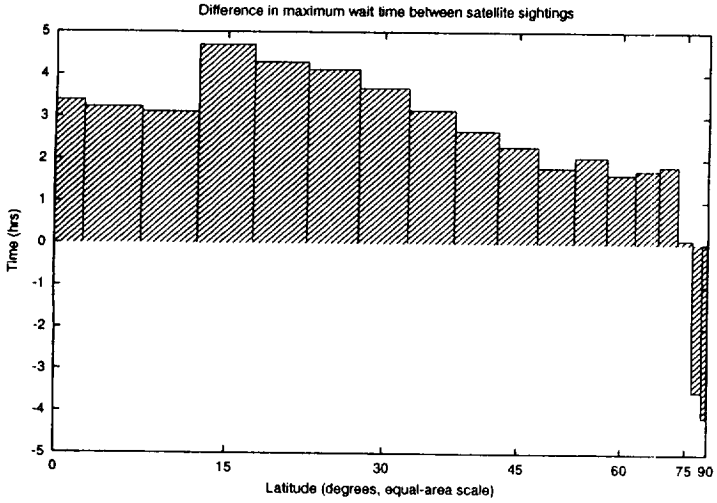
Satellite #	alt_p (km)	alt_a (km)	inc (deg)	Ω (deg)	ω (deg)	M (deg)
1	400	3000	111	0	0	0
2	400	3000	111	0	180	0
Maximum wait (over 10 days): 666.0 minutes						

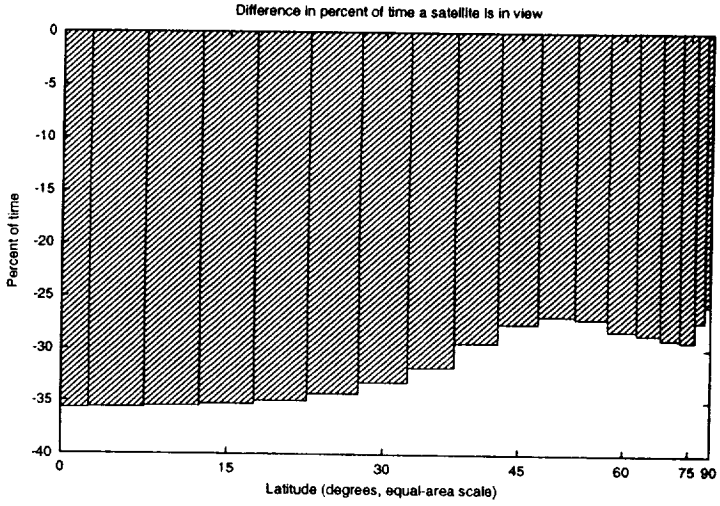


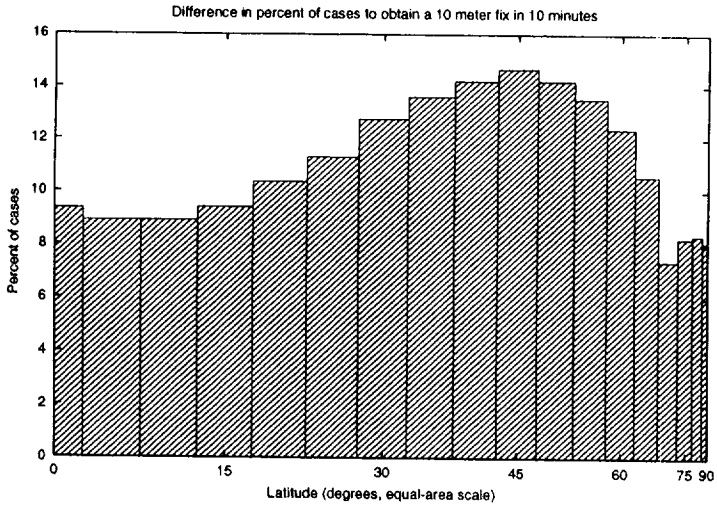
[Eccentric (C)] - [Eccentric (A)]

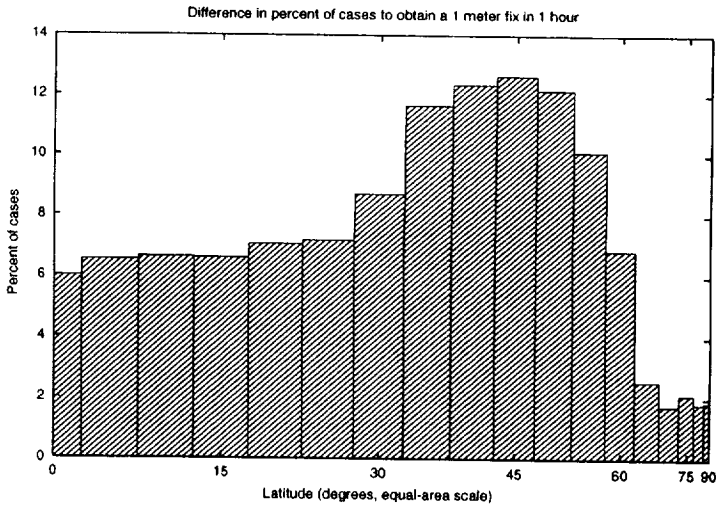






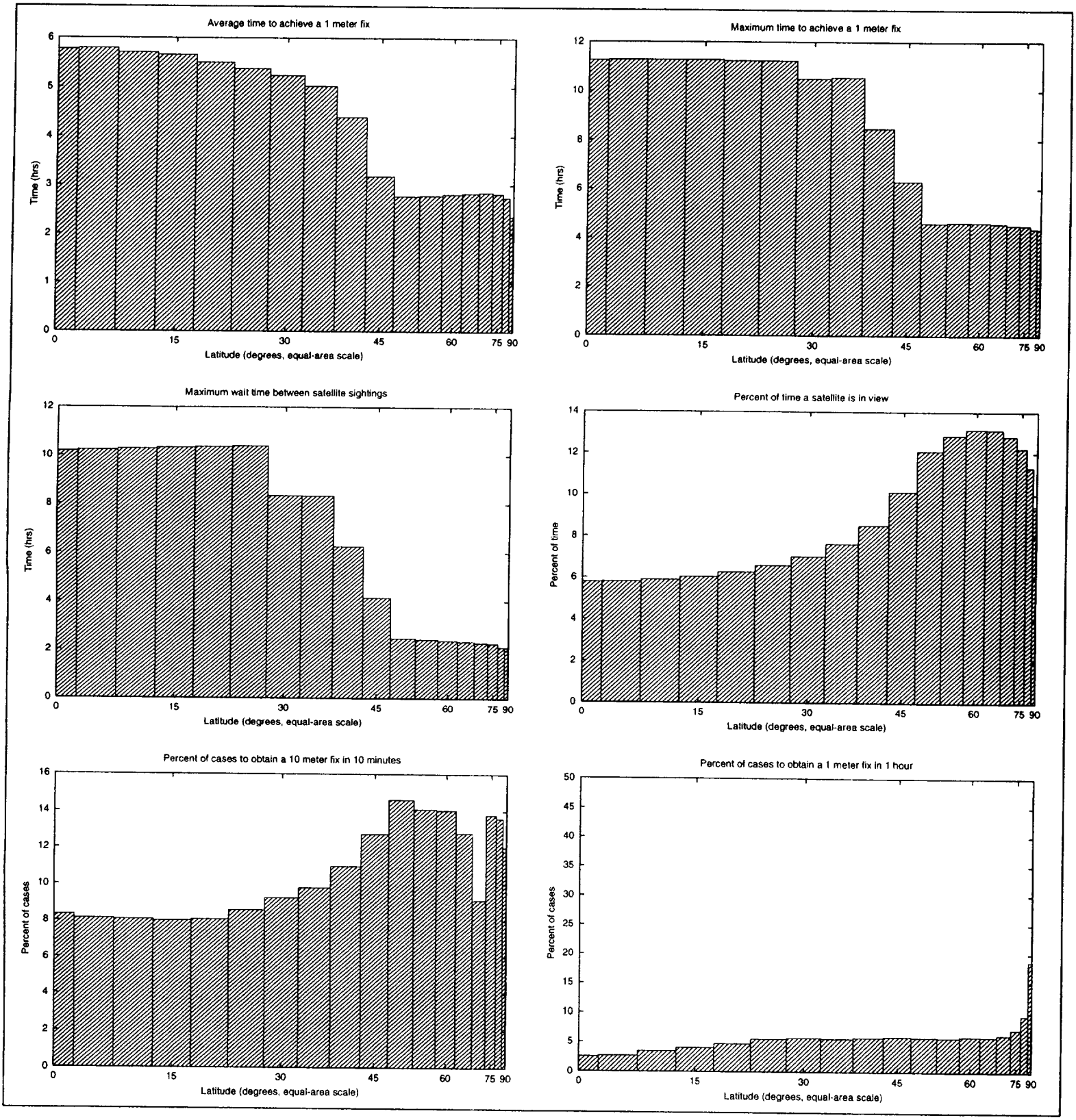






Circular (A)

Satellite #	alt_p (km)	alt_a (km)	inc (deg)	Ω (deg)	ω (deg)	M (deg)
1	800	800	111	180	0	0
2	800	800	111	0	0	0
Maximum wait (over 10 days): 622.8 minutes						



[Circular (A)] - [Eccentric (A)]