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Dilution-of-Precision-Based Lunar Surface Navigation System Analysis Utilizing Lunar Orbiters

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April 2007

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Summary

The NASA Vision for Space Exploration is focused on the return of astronauts to the Moon. Although navigation systems have already been proven in the Apollo missions to the Moon, the current exploration campaign will involve more extensive and extended missions requiring new concepts for lunar navigation. In contrast to Apollo missions, which were limited to the near-side equatorial region of the Moon, those under the Exploration Systems Initiative will require navigation on the Moon's limb and far side. Since these regions have poor Earth visibility, a navigation system comprised solely of Earth-based tracking stations will not provide adequate navigation solutions in these areas. In this report, a dilution-of-precision (DoP)-based analysis of the performance of a network of Moon orbiting satellites is provided. This analysis extends a previous analysis of a lunar network (LN) of navigation satellites by providing an assessment of the capability associated with a variety of assumptions. These assumptions pertain to the minimum surface user elevation angle and a total single satellite failure in the lunar network. The assessment is accomplished by making appropriately formed estimates of DoP. Different adaptations of DoP, such as geometric DoP and positional DoP (GDoP and PDoP), are associated with a different set of assumptions regarding augmentations to the navigation receiver or transceiver.

Introduction

In support of NASA's Vision for Space Exploration (ref. 1), extension of the position-fixing capability provided by the GPS constellation (ref. 2) to the Moon is being analyzed. This extension would be provided through the introduction of a lunar network (LN) of spacecraft orbiting the Moon (ref. 3). This study provides a dilution-of-precision (DoP)-based analysis of the navigation performance associated with a LN for a user located on the lunar surface. The current study is similar to a prior study on the subject (ref. 4) with two main differences: the use of newly developed DoP technique referred to as "generalized DoP" (R. Carpenter, 2005, Generalized Dilution of Precision, unpublished manuscript) and the extension to multiple minimum user elevation angles and the total single satellite failure (ref. 5).

Generalized DoP provides the ability to assess the navigational performance associated with a receiver that is able to integrate radiometric measurements over time. Such an analysis method allows one to directly compare the navigational capability associated with sparse constellations to that provided by constellations supporting full coverage of an appropriate fold. Estimates of user state that are derived from multiple radiometric measurements collected over a period of time are referred to herein as "dynamic," whereas those provided by full constellations that do not employ integration over time in the receiver are referred to as being "kinematic." As opposed to standard measures of DoP that are restricted to kinematic position-fixing capabilities, the use of generalized DoP further allows assessment of the constellation to be performed in terms of the latency associated with obtaining a specified level of system performance (ref. 5).

Several different options for the LN are considered in this study: standard Walker constellations, polar/circular constellations, Lang-Meyer constellations, and special constellations that include navigation spacecraft in highly elliptical orbits (refs. 6 to 9). These constellations are also studied under the possibility of the total failure of a single satellite. Various minimum user elevation angles are studied because there is not currently a requirement on the topic. Also included in the study are assessments of a number of augmentations to the system, such as highly stable clocks within the receiver, good knowledge of the terrain, and the integration of radiometric measurements over periods of time. Comparisons of the system performance under the different systems assumptions indicate that system availability performance is significantly improved and latency is reduced by the prescribed augmentations. In particular, although using a highly stable clock for the user receiver brings about an improvement in performance, the improvement in performance brought about by the knowledge of user altitude alone is significantly greater than that brought about by a stable user clock. In addition, using a stable user clock together with knowledge of user altitude provides significant improvements over knowledge of user altitude alone. Further shown is that the use of time integration of radiometric measurements is an effective way to improve system availability to required levels. Finally, system performance is reduced with an increase in the minimum provider elevation angle as a result of the decrease in visibility.

The generalized DoP approach can be applied along with a variety of assumptions regarding navigation receiver and satellite visibility for versions of DoP, such as geometric and positional DoP (GDoP and PDoP), with varying requirements for the number of satellites in view to obtain a solution. For example, the basis for assessment (for a two-way mode of operation) is the PDoP, which assumes that the navigation transceiver only needs to solve for the user's position in three dimensions. Appropriate versions of DoP (or generalized DoP) are applied according to the assumptions regarding the nature of the radiometric measurements that are available in addition to assumptions regarding the availability of collateral information, such as synchronized clock or altitude above the lunar geoid. The user altitude is obtained from accurate knowledge of terrain coupled with user latitude and longitude. User latitude and longitude would be obtained from radiometric measurements. Results are derived from temporally and spatially averaged system availability numbers associated with prespecified levels of system availability. Results are also provided in terms of system latency associated with a prespecified level of system availability.

Constellations

Four categories of LN constellations are considered: polar (ref. 6), Walker (ref. 7), Lang-Meyer (ref. 9), and hybrid elliptical (ref. 9). The variations of the LN investigated all meet the requirement of providing continuous coverage by at least one satellite anywhere on the lunar surface at a minimum elevation angle of 10° for the surface user. The notation for the LN subsequently used is, for example, Lang-Meyer $N/p/f + x$, where N is the number of satellites, p is the number of orbital planes, f is the phasing in the mean anomaly between satellites in adjacent planes, and $+x$ is the possible added lunar satellites for equatorial coverage. Table 1 lists the parameters of the constellations considered herein.

TABLE 1.—LUNAR NETWORK CONSTELLATIONS

Constellation	Number of satellites	Number of planes	Semimajor axis (SMA), km	Inclination, deg	Eccentricity	Phasing number
Polar 12/4/1	12	4	9250	90	0	1
Polar 8/2/1	8	2	9250	90	0	1
Polar 6/2/1	6	2	9250	90	0	1
Hybrid elliptical 4/2/1+ 3	4	2	6541.4	62.9	0.6	1
	3	1	11 575	27.1	0	1
Walker 6/2/0	6	2	8050	52.2	0	0
Lang-Meyer 4/4/1+2	4	4	8050	58.9	0	1
	2	1	8050	0	0	1
Walker 5/5/1	5	5	9150	43.7	0	1

The analysis in this document is also performed for a single failure mode of operation to determine loss of performance if there is a satellite outage. It is assumed that the outage is the worst case, in that the outage is permanent. Table 2 lists the parameters of the constellations in the failure mode. Note that if a constellation can have multiple failure modes due to the asymmetry in the constellation, then it will have different failure mode versions identified in the table.

TABLE 2.—FAILURE MODE LUNAR NETWORK CONSTELLATIONS

Constellation	Number of satellites	Number of planes	Semimajor axis (SMA), km	Inclination, deg	Eccentricity	Phasing number
Polar 12/4/1	11	4	9250	90	0	1
Polar 8/2/1	7	2	9250	90	0	1
Polar 6/2/1	5	2	9250	90	0	1
Hybrid elliptical 4/2/1 + 3, V1	3	2	6541.4	62.9	0.6	1
	3	1	11 575	27.1	0	1
Hybrid Elliptical 4/2/1 + 3, V2	3	2	6541.4	62.9	0.6	1
	3	1	11 575	27.1	0	1
Hybrid Elliptical 4/2/1 + 3, V3	4	2	6541.4	62.9	0.6	1

Each of the constellations in this study was considered for specific reasons. The polar constellations are considered for providing a focus of coverage over the polar region. The polar 6/2/1 has the minimum number of satellites needed for a circular polar orbit constellation to provide single-fold global coverage. The polar 8/2/1 provides improved navigation performance and adds significant robustness because it can experience a loss of two satellites and maintain global coverage. The polar 12/4/1 is chosen for its ability to provide nearly continuous fourfold coverage over the lunar poles. Walker constellations focus coverage over the equatorial regions. The Walker 5/5/1 constellation offers the absolute minimum number of satellites in circular orbit planes to give global coverage, whereas the Walker 6/2/0 maximizes the elevation angle at the edge of coverage. To reduce the semimajor axes of the LN, a Lang-Meyer is considered. The hybrid elliptical constellation provides a focus of polar coverage and minimal orbital maintenance by placing the elliptical satellites into "frozen orbits." Images of these constellations are presented in appendix A.

Analysis

Generalized DoP

The analysis performed is a generalized version of the DoP metric (ref. 5), of which several forms are subsequently used for analysis. The generalized DoP is derived from the observability grammian, which is obtained by using the navigation user equations of motion and the associated sequence of measurements. The equations of motion and the measurement sequence are given by reference 5. It is shown that the DoP metric takes the following form, derived in reference 5:

$$\sqrt{\max\left\{eig\left[\left(\sum_{t_o}^{t_n}\widetilde{H}_o^T W \widetilde{H}_o\right)\right]\right\}} \tag{1}$$

where t_n is the n^{th} time step since time step zero; t_o is time step zero; $\widetilde{H}_o^T$ is the matrix transpose of $\widetilde{H}_o$, which is the measurement partial derivative matrix; and W is the measurement weighting matrix.

Variations of Generalized DoP

To relax the constraint of satellite coverage so as to invert the observability grammian, a number of augmentations to the lunar navigation system are considered in the analysis. These augmentations constrain the navigation solution and thereby reduce the number of required satellites in view. The augmentations include clock synchronization and a good knowledge of the terrain, which result in several forms of DoP. The selected form of DoP used not only affects the required satellites in view but also affects the state transition and H-matrices used in the calculation. Also, note that throughout the analysis, both range and range-rate (Doppler) measurements are used to solve for position and time-bias (when appropriate) estimates only. No estimates were made for velocity or frequency bias, as the users are assumed to be stationary.

Geometric dilution of precision (GDoP) is used in the global positioning system (GPS) where the solution is obtained for the position of the user in three dimensions and for the time bias, resulting in the requirement of four navigation signals. The associated H-matrices and state transition for stationary surface users are

$$\Phi_{GDoP}(t_i, t_o) = I + \begin{bmatrix} 0 & I \\ 0 & 0 \end{bmatrix} \times (t_i - t_o) \tag{2}$$

where Φ is the state transition matrix; t_i is the i^{th} time step since time step zero; and I is the identity matrix.

$$H = \begin{bmatrix} \frac{\partial r_1}{\partial x_1} & \frac{\partial r_1}{\partial y_1} & \frac{\partial r_1}{\partial z_1} & \frac{\partial r_1}{\partial (ct_{\text{bias}_1})} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{\partial r_m}{\partial x_m} & \frac{\partial r_m}{\partial y_m} & \frac{\partial r_m}{\partial z_m} & \frac{\partial r_m}{\partial (ct_{\text{bias}_m})} \\ \bullet & \bullet & \bullet & \bullet \\ \frac{\partial \dot{r}_1}{\partial x_1} & \frac{\partial \dot{r}_1}{\partial y_1} & \frac{\partial \dot{r}_1}{\partial z_1} & \frac{\partial \dot{r}_1}{\partial (ct_{\text{bias}_1})} \\ \vdots & \vdots & \vdots & \vdots \\ \bullet & \bullet & \bullet & \bullet \\ \frac{\partial \dot{r}_m}{\partial x_m} & \frac{\partial \dot{r}_m}{\partial y_m} & \frac{\partial \dot{r}_m}{\partial z_m} & \frac{\partial \dot{r}_m}{\partial (ct_{\text{bias}_m})} \end{bmatrix} \tag{3}$$

where r is the pseudorange/range signal (dependent on one-way/two-way navigation system); r_m is the m^{th} observed pseudorange/range signal (dependent on one-way/two-way navigation system); and ct_{bias} is the speed of light multiplied by the clock bias.

Positional dilution of precision (PDoP) provides an estimate of user positioning accuracy for the case in which there is no time bias between orbiter clocks and user clocks, such as the case in a two-way mode of operation. PDoP results in the requirement of three navigation signals. The associated H-matrices and state transition for stationary surface users are

$$\Phi_{PDoP}(t_i, t_o) = I + \begin{bmatrix} 0 & I \\ 0 & 0 \end{bmatrix} \times (t_i - t_o) \tag{4}$$

$$H = \begin{bmatrix} \frac{\partial r_1}{\partial x_1} & \frac{\partial r_1}{\partial y_1} & \frac{\partial r_1}{\partial z_1} \\ \vdots & \vdots & \vdots \\ \frac{\partial r_m}{\partial x_m} & \frac{\partial r_m}{\partial y_m} & \frac{\partial r_m}{\partial z_m} \\ \bullet & \bullet & \bullet \\ \frac{\partial \dot{r}_1}{\partial x_1} & \frac{\partial \dot{r}_1}{\partial y_1} & \frac{\partial \dot{r}_1}{\partial z_1} \\ \vdots & \vdots & \vdots \\ \bullet & \bullet & \bullet \\ \frac{\partial \dot{r}_m}{\partial x_m} & \frac{\partial \dot{r}_m}{\partial y_m} & \frac{\partial \dot{r}_m}{\partial z_m} \end{bmatrix} \tag{5}$$

Horizontal/time dilution of precision (HTDoP) is applied when a user has knowledge of his altitude above the center of the Moon but a time bias exists, resulting in the requirement of three navigation signals. The associated H-matrices and state transition for stationary surface users are

$$\Phi_{HTDoP}(t_i, t_o) = I + \begin{bmatrix} 0 & I \\ 0 & 0 \end{bmatrix} \times (t_i - t_o) \tag{6}$$

$$H = \begin{bmatrix} \frac{\partial r_1}{\partial x_1} & \frac{\partial r_1}{\partial y_1} & \frac{\partial r_1}{\partial (ct_{bias_1})} \\ \vdots & \vdots & \vdots \\ \frac{\partial r_m}{\partial x_m} & \frac{\partial r_m}{\partial y_m} & \frac{\partial r_m}{\partial (ct_{bias_m})} \\ \bullet & \bullet & \bullet \\ \frac{\partial \dot{r}_1}{\partial x_1} & \frac{\partial \dot{r}_1}{\partial y_1} & \frac{\partial \dot{r}_1}{\partial (ct_{bias_1})} \\ \vdots & \vdots & \vdots \\ \bullet & \bullet & \bullet \\ \frac{\partial \dot{r}_m}{\partial x_m} & \frac{\partial \dot{r}_m}{\partial y_m} & \frac{\partial \dot{r}_m}{\partial (ct_{bias_m})} \end{bmatrix} \tag{7}$$

Horizontal dilution of precision (HDoP) provides an estimate of user positioning accuracy when both time and user altitude are known and only two navigation signals are required, as in the case of a two-way mode of operation with good knowledge of terrain. The associated H-matrices and state transition for stationary surface users are

$$\Phi_{HDoP}(t_i, t_o) = I + \begin{bmatrix} 0 & I \\ 0 & 0 \end{bmatrix} \times (t_i - t_o) \tag{8}$$

$$H = \begin{bmatrix} \frac{\partial r_1}{\partial x_1} & \frac{\partial r_1}{\partial y_1} \\ \vdots & \vdots \\ \frac{\partial r_m}{\partial x_m} & \frac{\partial r_m}{\partial y_m} \\ \bullet & \bullet \\ \frac{\partial \dot{r}_1}{\partial x_1} & \frac{\partial \dot{r}_1}{\partial y_1} \\ \vdots & \vdots \\ \bullet & \bullet \\ \frac{\partial \dot{r}_m}{\partial x_m} & \frac{\partial \dot{r}_m}{\partial y_m} \end{bmatrix} \tag{9}$$

System Availability

The underlying figure of merit (FOM) used for evaluating the performance associated with a navigation system is system availability. System availability (SA) is defined herein as the proportion of time that the navigation system is predicted to provide performance at or below a specified level of DoP. In other words, the navigation system is defined as "available" when the appropriately chosen version of DoP falls below a certain threshold. For this study, the threshold is set at 10. Furthermore, a DoP of 10, coupled with a 1-m user range error (URE), implies a user state uncertainty of 10 m, which is sometimes used as a required level of performance for lunar position fixing. System availability is calculated herein for a large number of points on the surface of the Moon. The results provided below are in terms of system availability for a given latency. Equation 10 describes how the system availability FOM is calculated. This results in an estimate of the percentage of time that the system availability condition has been satisfied. The system availability analysis is performed for the constellations listed in table 1.

$$SA = 100 \times \frac{\sum_{m=1}^{t_n} \cos(lat_m) \times \sum_{n=1}^{t_f} (DoP_{n,m} <= \text{threshold})}{t_f \times n_{\text{long}} \times \sum_{m=1}^{n_{\text{lat}}} \cos(lat_m)} \tag{10}$$

where t_n is the total number of points in the simulation; t_f is the number of time epochs in the simulation, n_{long} is the number of longitude points in the simulation; and n_{lat} is the number of latitude points in the simulation.

Failure System Availability

The failure system availability analysis simulates the event of a total outage of one node of the navigation system for the entire sidereal lunar month duration of the analysis. For the LN, any one of the satellites in the constellation can be dropped out if the constellation is symmetric. If the constellation is not symmetric, such as the hybrid elliptical 4/2/1 + 3, the failure analysis is performed for each of the orbital planes. In the case of the hybrid elliptical 4/2/1 + 3, there is a plane covering the north, south, and equatorial regions; therefore, the failure analysis is run three times to determine the performance of a satellite outage in each orbital plane. The failure system availability analysis is otherwise identical in procedures and presentation of results to the system availability analysis. This analysis is performed for the constellations listed in table 2.

System Latency

A secondary FOM used for evaluating the performance associated with a navigation system is system latency (SL), which is defined as the latency that is required to obtain the minimum global system availability. For the global region to meet this minimum system availability, the most appropriate method would be for each point on the surface to also meet this minimum system availability. Therefore, latency is determined at each point on the surface as the amount of integration time in the generalized DoP measurements until the minimum system availability criterion is met. For the analysis presented herein, the two minimum system availabilities used to determine the system latency were 90 and 99 percent. Also, it is important to state that the system latency analysis does not include the augmentation of "free-wheeling" (i.e., open-loop clock synchronization) the user clock for 3 hr before the next time synchronization. One final comment is that a maximum system latency of 1440 min (1 day) is allowed in the simulation.

Failure System Latency

The failure system latency analysis simulates the same type of outage as that in the failure system availability analysis, but the type of analysis differs from that performed for the system latency analysis. The failure system latency analysis is otherwise identical in procedures and presentation of results to the system latency analysis. This analysis is performed for the constellations listed in table 2.

Assumptions

Navigation signal**.—**The navigation signal requirements used in this study are outlined in table 3.

TABLE 3.—NAVIGATION SIGNAL ASSUMPTIONS

Doppler measurement frequency, GHz	GPS L1 (1.57545)
User range error (URE), m	1
User range rate error (URRE), mm/sec	0.1
Minimum elevation angle, deg	5, 10, 15

Simulation**.—**The lunar surface is taken as a set of 600 points on the surface, spaced evenly in latitude and longitude. The longitudes for the points go from −180° to 180° in 15° increments, and the latitudes of the points go from –90° to 90° in 7.5° increments. Technically, this grid of points results in 625 points of interest, but the points at 180° longitude are at the same location as the points at −180° longitude, so one set of the 25 points is removed for the sake of not duplicating and not biasing the results. The analysis is performed over the duration of 1 lunar sidereal month (27.3 Earth days) where DoPs are calculated at an epoch rate of 5 min. The starting epoch for the simulations is July 15, 2009 00:00:00.000 GMT. Visibility to the constellations from the surface points is computed based on three minimum user elevation angles of 5°, 10°, and 15°.

User burden.**—**Receivers that support a reduced number of satellites will have associated with them an increased level of processing or other sensing equipment. This situation leads to increased user burden in terms of the mass and power the host platform must provide to the navigation receiver. To provide knowledge sufficient to infer user altitude given a horizontal location, a large digital elevation map would have to be available to the user. To provide an error comparable to the 1-m URE assumed for the system, the user is required to store approximately 1 TB of terrain data for global coverage. For the user to have knowledge of terrain within a 30-km radius of a starting point, approximately 100 MB is required for storage.

For a navigation system using one-way radiometric signals as a mode of operation, the clock synchronization assumption implies that the clocks would have to be stable enough to have the ability to free-wheel for a number of hours after synchronization. User clocks would then require periodic synchronization with orbiting clocks. The threshold used to synchronize the clock is a GDoP ≤ 5 with no knowledge of the terrain or an HTDoP ≤ 5 with good knowledge of terrain. Therefore, a requirement of four and three measurements, respectively, would be imposed. The reduced DoP value from 10 to < 5 is assuming that the transfer of time would require a more accurate solution than is nominally needed. The availability analyses are performed assuming a clock resynchronization period of 3 hr. The low mass, volume, and power expected for highly stable oscillators will make this system a viable option. The clock synchronization is not a requirement when using two-way radiometric navigation signals for the system's mode of operation. Table 4 lists the forms of DoP used in the analysis together with their corresponding assumed system requirements.

TABLE 4.—DOP ASSUMPTIONS SUMMARY

Knowledge of terrain	Synchronized clock	Dilution-of-precision (DoP) requirement	Number of measurements required
No	No	GDoP 10	4
Yes	No	HTDoP 10	[a]3
No	Yes/(two way)	PDoP [b]10	3
Yes	Yes/(two way)	HDoP [c]10	[a]2

[a]Terrain knowledge of latitude and longitude.
[b]If one-way GDoP, five required to synchronize clock.
[c]If one-way HTDoP, five required to synchronize clock.

Results

Results are reported as the four system analyses (system availability, failure system availability, system latency, and failure system latency) for each of the three minimum user elevation angles (5°, 10°, and 15°) and are presented in tabular form for selected areas on the face of the Moon:

1. Global: all latitudes and longitudes; entire lunar surface coverage
2. South pole: latitudes within 10° of lunar south pole; all longitudes
3. Front equatorial: latitudes from 45° N to 45° S; longitudes from 90° W to 90° E (near side)
4. Back side: all latitudes and longitudes pertaining to far side of the Moon
5. Apollo: latitudes and longitudes within the bounds of landed Apollo missions

The south pole analysis is performed to determine the system availability in the context of Lunar Outpost missions that are expected to focus on concentrated exploration of the south pole. The front equatorial analysis is provided in the context of extended Apollo-like missions. The back-side analysis illustrates the problems (due to lack of visibility) of using only Earth-based assets. Finally, the Apollo region gives information about the actual Apollo landing sites.

The term "no terrain" indicates that there is no detailed cartography of the terrain that would allow determining the altitude of the user. The term "good terrain" indicates that there is such knowledge and that an accurate estimate of user altitude above the lunar datum is available to the navigation receiver. The term "no clock" indicates that the user clocks and orbiter clocks are not synchronized, and the term "good clock" indicates that the clocks are synchronized and remain so for a specific number of hours (indicated by τ), given a GDoP or HTDoP less than or equal to 5. If the system is operating in a two-way mode, then the concepts associated with GDoP or HTDoP do not apply.

For the system availability and failure system availability analyses, results are summarized in stoplight charts, which show the performance of each of the constellations proposed herein in terms of the latency required to achieve 90-percent system availability over a specified region of the surface of the Moon. In this table a green box indicates that the criterion is met in a kinematic sense (i.e., with zero latency). If the criterion is not met with kinematic measurements but is met with a dynamic fix of 15 min, the box is shaded yellow. If the criteria are not met by either of these metrics but are met with a dynamic fix of 1 hr, it is shaded red; otherwise, it is shaded gray, indicating that the constellation does not meet the 90-percent system availability within 1 hr. It does not mean that the system does not meet the 90-percent system availability at all; it indicates that it will take more than 1 hr to do so.

Appendix B illustrates the performance of the various constellations given the various DoPs and integration periods. The images shown in this appendix are the system availabilities for the seven lunar constellations. Each constellation on each image is superimposed over a gray-scale image of the Moon's surface with the center of the image being the latitude-longitude pair of (0° N, 0° E). The black colors on the superimposed system availabilities imply 0 percent. However, as the colors move from black, to red, to yellow, to white, the system availabilities go up to 100 percent. Following each figure is a table that lists the system availabilities for the five regions identified above. A second table is presented for the failure system availability analysis and lists the losses in system availability from the nonfailure mode analysis.

For the system latency and failure system latency analyses, results cannot be summarized in a stoplight chart as they were for the system availability analyses. The reason is that the variable in the system latency analyses is the integration time, unlike the system availability analyses in which set latencies were in place. However, results can be plotted and tabulated similarly to the system availability analyses and are done so in appendix C. Again, the results of the system latency analysis are superimposed over a gray-scale image of the Moon's surface with the center of the image being the latitude-longitude pair of (0° N, 0° E). However, the superimposed system latencies are dependent on the overall system latency range for the set of plots. The longest latency will be identified and will be shaded black. As the latencies decrease to 0 min (kinematic position fixes), the shading will go from black, to red, to yellow, and then to white. Following each figure is a table that lists the system latencies for the five regions identified earlier in this section. A second table is given for the failure system latency analysis and lists the increases in system latency from the nonfailure mode analysis.

The remainders of this section, along with appendixes B and C, are divided into the multiple minimum elevation angle sets that were completed for this analysis. The minimum elevation angles imposed on the surface users were 5°, 10°, and 15°. Within each minimum elevation angle section, four subsections contain results from the nonfailure mode and failure mode analyses for system availability and system latency.

Minimum Surface Elevation Angle of 5°

This section shows the nonfailure mode and failure mode system availability and system latency results for surface points requiring a minimum elevation angle of 5°. Illustrations of the results and tabulated data per region can be found in appendix B.1 for system availability analyses results and appendix C.1 for system latency analyses results.

System availability results.—Figure 1 shows the stoplight chart of the performance of each of the systems proposed in this report in terms of the latency required to achieve a

90-percent system availability over a specified region of the surface of the Moon. Inspection of the latency result summary provided in figure 1 reveals three overall general trends apparent in each of the identified lunar regions. The first general trend is that latency improves for a given constellation as the augmentations are added. In particular, the improvement in performance brought by knowledge of user altitude alone is significantly greater than that brought by a highly stable user clock alone. Using a highly stable user clock together with knowledge of user altitude provides significant improvements over knowledge of user altitude alone.

The second general trend observed for each identified region is that the system performance improves with the number of satellites in the constellation. Notable exceptions to this trend are present for the hybrid elliptical. For example, the polar 6/2/1 and inclined 6/2/0 satellite constellations provide better system availability than the hybrid elliptical case that contains seven satellites using no knowledge of user altitude and no onboard clock when front equatorial coverage is required for a two-way system.

The third general trend is that for the one-way and two-way modes of operation, the two-way mode is better able to provide a navigation solution in all the regions. This trend is apparent in the front equatorial region for the polar 6/2/1 and the inclined 6/2/0, where even when clock synchronization with a τ of 3 hr is used to simulate the performance of a two-way system, the one-way measurement is not able to meet the two-way performance. Results in appendix B.1 show improvements in system availability above the 90-percent threshold in the stoplight chart for the two-way system over the one-way system. The analysis shows that when using a two-way system, the polar 8/2/1 constellation can give kinematic navigation solutions at or above 90 percent of the time over the lunar globe. The polar 6/2/1 can provide a

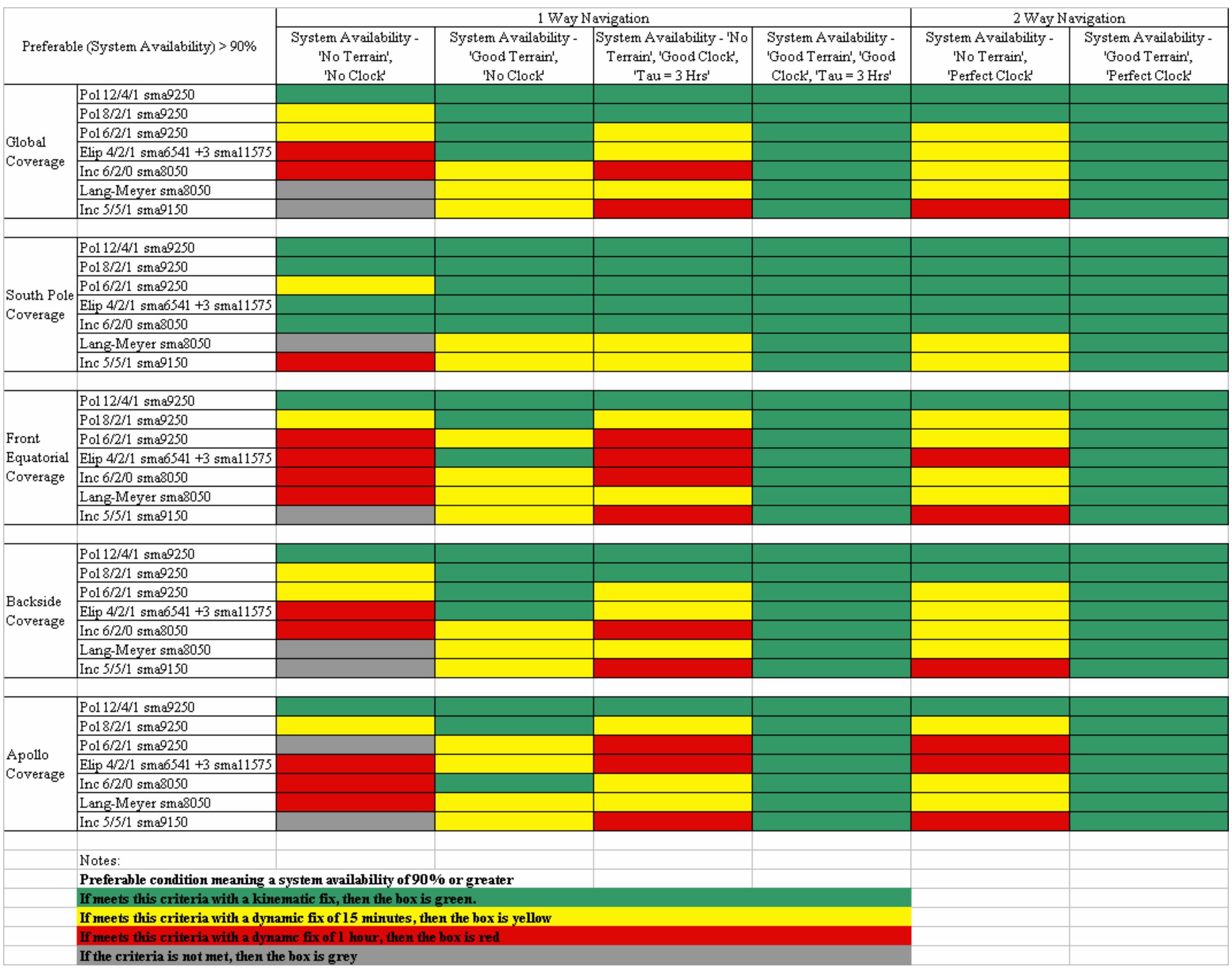

Figure 1.—Stoplight chart for system availability results at 5° elevation angle.

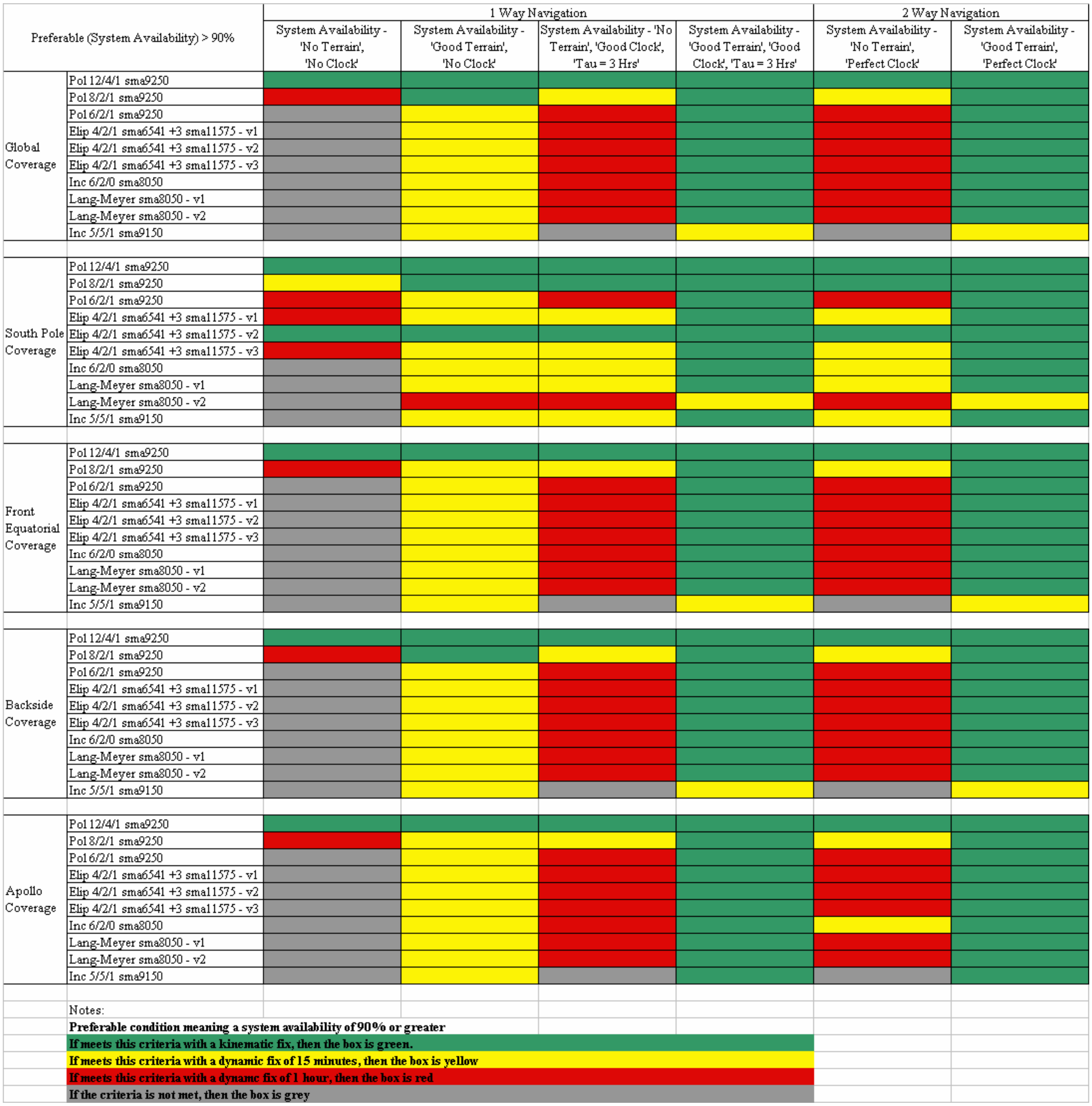

Figure 2.—Stoplight chart for failure system availability results at 5° elevation angle.

15-min dynamic solution for global coverage and a kinematic solution for the polar region given a two-way system or augmentations to a one-way system. Note also that the sensitivity of latency to the number of orbiters is higher for the kinematic solutions than that for the dynamic solutions of 15 min and 1 hr.

Failure system availability results.—Figure 2 shows the stoplight chart of the performance of each of the systems proposed in this report in terms of the latency required to achieve 90-percent system availability over a specified region of the surface of the Moon for the single-mode failure constellations.

The total loss of one satellite caused all constellations except the polar 12/4/1 to have discontinuous coverage. This results in sensitivity to the number of orbiters in the constellation not being as important a factor, unlike the nonfailure mode of operation. This sensitivity is especially the case when both augmentations are not a part of the system.

When in the one-way mode of operation with both augmentations or the two-way mode with terrain information, only the inclined 5/5/1 suffers degradation from the kinematic solution for the global region. Similar statements can be made for the south pole region, but the constellation that degrades is the Lang-Meyer version 2. Additional comparisons can be made from the data present in appendix B.1.

System latency results.—The results provided in appendix C.1.1 to C.1.4 for the 90-percent system availability case and in appendix C.1.5 to C.1.8 for the 99-percent system availability case reveal the same trends that were seen in the system availability analysis. In general, latency to reach the minimum system availability decreases for a given constellation as the various augmentations are added. This result is similar to the way the augmentations affected the system availability results. The second general trend observed for each identified region is that the system latency decreases with an increase in the number of satellites in the constellation. One notable exception to this trend is present for the hybrid elliptical. For example, the polar 6/2/1 satellite constellation provides a lower latency than the hybrid elliptical constellation that contains seven satellites (under the assumption of no knowledge of user altitude or a highly stable onboard clock) when global coverage is required.

The third general trend concerns the one-way and two-way modes of operation: the two-way mode of operation provides lower system latencies than the one-way mode of operation. This result is again consistent with those of the system availability analysis. Also, the general trend between having and not having terrain information is that having terrain information improves system latency just as having terrain information improves system availability.

It is important to note the difference between the system availability analysis and the system latency analysis. In the system availability analysis, the polar 6/2/1 could provide a 90.69-percent availability for the global region using a one-way system without terrain information or clock synchronization if the latency were 15 min. This 90.69-percent availability does not mean that every point on the surface has an availability of 90.69 percent but that the spatially weighted availability for all points on the surface is 90.69 percent. However, for the system latency analysis, there is a strict requirement that all points on the surface have a 90-percent system availability, and then the latency to achieve such availability is determined for all points on the surface. This requirement results in a spatially weighted system latency of 29.39 min. However, it is seen that this 29.39-min latency is not a multiple of the measurement epoch, so it is apparent that some of the surface points have a higher latency, such as 30 min, whereas others may have a lower latency, such as 25 min.

It should also be noted that there is a difference between the system latency results for the 90-percent system availability requirement and the 99-percent system availability requirement. In all constellations and for all augmentation schemes, the system latency for the 99-percent system availability was at least, if not larger than, the system latency for the 90-percent system availability. An example of where the system latency stayed constant was the polar 12/4/1 constellation, which was attributed to the system latency being 0 min. In the one-way mode of operation without terrain information for the global region, the polar 6/2/1 had a weighted system latency of 29.39 min for the 90-percent system availability and 38.95 min for the 99-percent system availability. However, in the same augmentation scheme in the global region, the inclined 6/2/0 had a weighted system latency of 51.64 min for the 90-percent system availability and 114.64 min for the 99-percent system availability.

Regarding the system in two-way mode of operation with terrain information for the global region, the polar 6/2/1 had a weighted system availability of 0 min for the 90-percent system availability and 7.80 min for the 99-percent system availability. However, in the same augmentation scheme in the global region, the inclined 6/2/0 had a weighted system latency of 1.20 min for the 90-percent system availability and 2.86 min for the 99-percent system availability. This result shows that not all constellations are affected in the same manner when trying to attain the 99-percent system availability requirement. More comparisons that are similar to these can be made from the data in appendix C.1.

Failure system latency results.—Results for the failure system latency analysis for the 5° elevation angle are also presented in appendix C.1.1 to C.1.4 for the 90-percent system availability case and in appendix C.1.5 to C.1.8 for the 99-percent system availability case. Tables in appendix C.1.1 and C.1.5 show that the increases in the weighted system latency result from the total loss of one satellite. For the 90-percent system availability case, increases in weighted system latency for the one-way mode of operation without terrain information in the global region ranged from 0 min (polar 12/4/1) to about 21 min (polar 8/2/1), to between 40 to 90 min for the remaining constellations. However, for the 99-percent system availability case, increases in weighted system latency for the one-way mode of operation without terrain information in the global region ranged from just over 0 min (polar 12/4/1) to between 70 and 205 min with the polar 6/2/1 having the largest increase in weighted system latency of 204.71 min. These data show that increasing the system availability requirement to 99 percent has a more profound effect for the polar 6/2/1 than for any other constellation when one satellite is unavailable.

For the system in two-way mode of operation with terrain information for the global region, all constellations had weighted system latency increases of less than 4 min at the 90-percent system availability requirement. However, when requiring a 99-percent system availability, increases in weighted system latency ranged from 0 min (polar 12/4/1) to up to 180 min. The polar 6/2/1 had an increase of 69.56 min when requiring a 99-percent system availability, but only an increase of 1.39 min for the 90-percent system availability. Many more similar comparisons can be made from the data in appendix C.1.

Minimum Surface Elevation Angle of 10°

This section shows the nonfailure mode and failure mode system availability and system latency results for surface points requiring a minimum elevation angle of 10°. Illustrations of the results and tabulated data per region can be found in appendix B.2 for system availability analyses results and in appendix C.2 for system latency analyses results.

***System availability results*.**—Figure 3 shows the stoplight chart of the performance of each of the systems proposed herein in terms of the latency required to achieve 90-percent system availability over a specified region of the surface of the Moon. Just as seen in the results from the system availability analysis for the 5° elevation angle presented in the previous section, the general trend was that latency improves as augmentations are added to the system. In the global region, the general trend is that two-way mode operation with terrain information outperforms one-way and two-way modes without terrain information. The sensitivity to latency on the number of orbiters is visible, as all the points have continuous access to a satellite at a 10° elevation angle.

Results for the 10° minimum elevation angle (app. B.2) can be compared with the results for the 5° minimum elevation angle (app. B.1). By comparing figure 3 (10°) to figure 1 (5°), it is also clear that there is degradation in performance with the increase in the minimum elevation angle. This degradation is due to the loss of visibility when the satellite elevation angle to the surface point is between 5° and 10°. For example, in the global region, when operating in the one-way mode without terrain information, the polar 12/4/1 is the only constellation that can provide kinematic solutions with a system availability of 90 percent. The polar 6/2/1 now cannot meet the 90-percent system availability within the 1-hr integration period. (The polar 6/2/1 has an 87.29-percent system availability after the 1-hr integration period.) For the global region, when in the two-way mode of operation without terrain information, only the polar 12/4/1 can meet the 90-percent system availability with kinematic solutions. The polar 8/2/1 can meet the

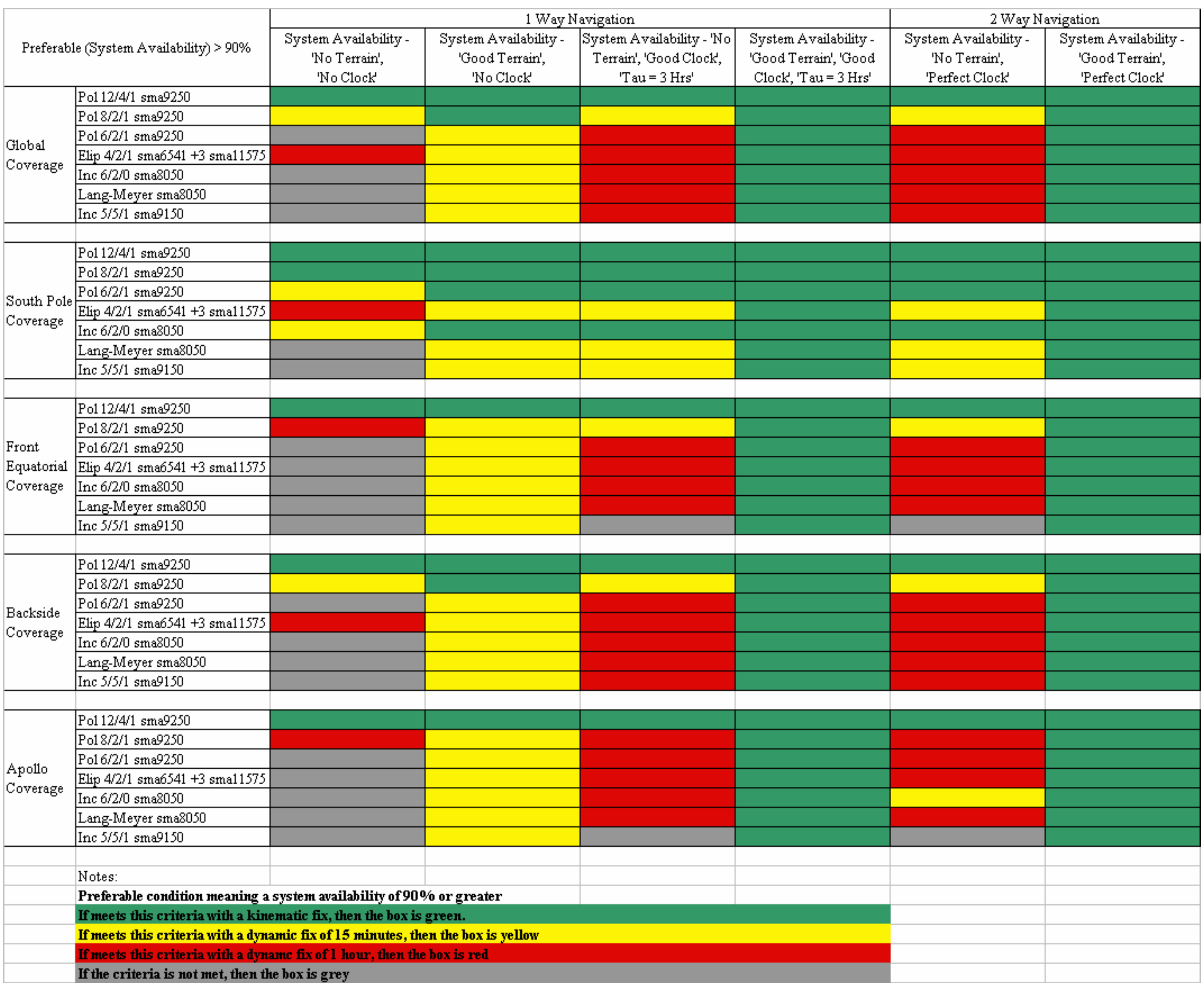

Figure 3.—Stoplight chart for system availability results at 10° elevation angle.

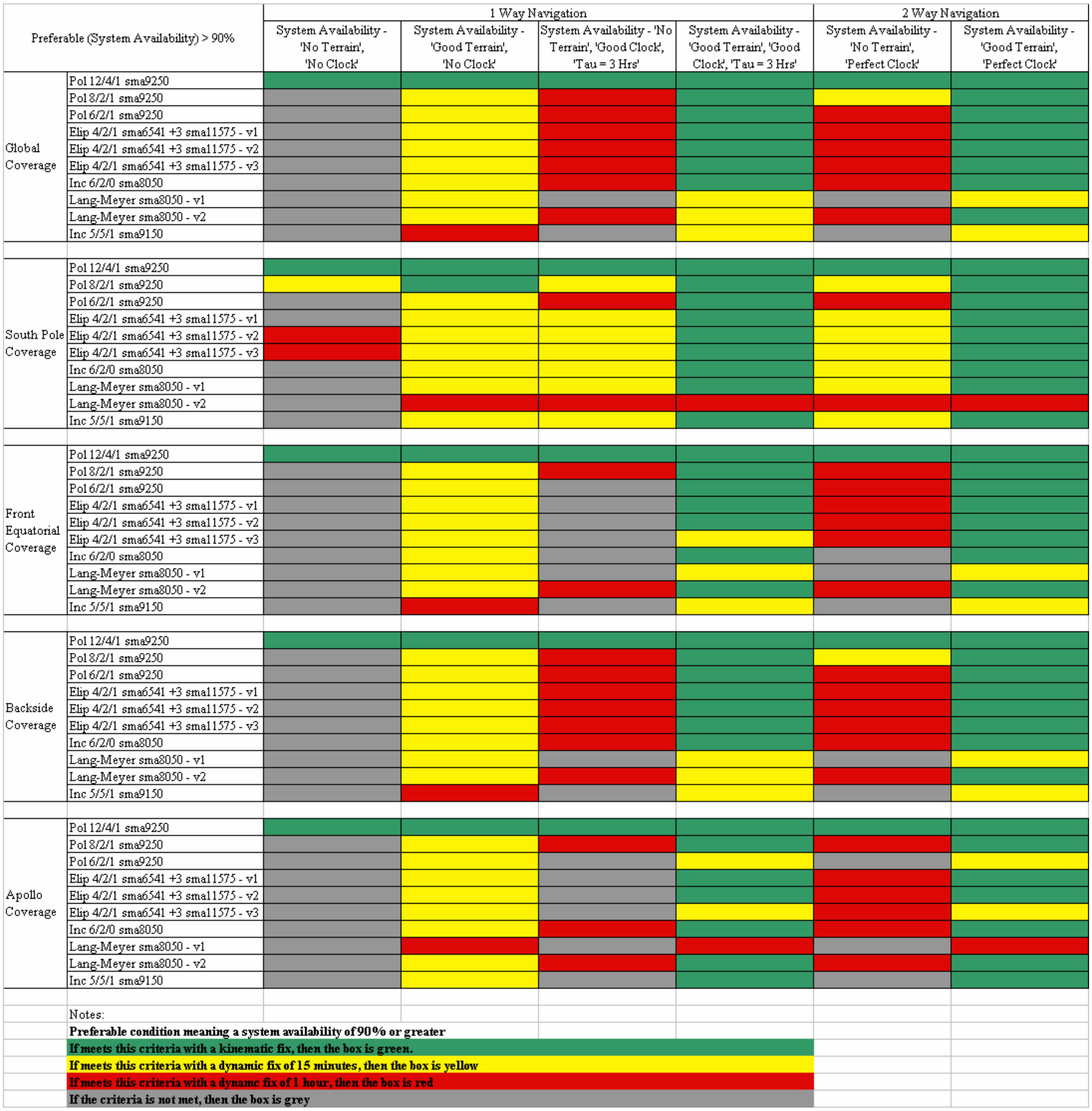

Figure 4.—Stoplight chart for failure system availability results at 10° elevation angle.

90-percent system availability with 15-min integration periods, whereas the other constellations can meet the 90-percent system availability with the 1-hr integration period. Prior results for the 5° minimum elevation angle showed that all constellations except the inclined 5/5/1 met the 90-percent system availability with kinematic or dynamic solutions with a 15-min integration period. This comparison clearly shows that the effect of increasing the minimum elevation angle is to reduce the system availability for given latencies.

Failure system availability results.—Figure 4 shows the stoplight chart of the performance of each of the systems proposed in this report in terms of the latency required to achieve 90-percent system availability over a specified region of the surface of the Moon for the single-mode failure constellations.

The total loss of one satellite again resulted in all constellations except the polar 12/4/1 having discontinuous coverage. This results in sensitivity to the number of orbiters in the constellation not being as important a factor, unlike the nonfailure mode of operation. As in the case for the 5° minimum elevation angle, there are interesting results for constellations with more than one failure mode, as in the hybrid elliptical and the Lang-Meyer. The various failure modes for these constellations do not perform in the same manner, so if there were a failure mode, it would be better in terms of system performance for the failure to occur in the hybrid elliptical version 2 or version 3 mode or in the Lang-Meyer version 2 mode.

It is also important to note the degradation that occurs when the minimum elevation angle is increased from 5° to 10° in the failure mode of operation. The tables presented in appendix B.2 show that the losses in weighted system availability may not be as large for some constellations (e.g., hybrid elliptical) as for others (e.g., polar 12/4/1) in comparison with the losses in failure system availability for the 5° minimum elevation angle. This is an artifact of the losses in system availability that occur when transitioning from 5° to 10° minimum elevation angle.

In the failure mode of operation, the only constellation that can provide kinematic solutions with a system availability of at least 90 percent is the polar 12/4/1, which requires no augmentations in the one-way mode. The polar 8/2/1 (with terrain information) can meet the 90-percent system availability in the south pole region. Most of the other constellations (except the Lang-Meyer or the inclined 5/5/1) can provide 90-percent system availability in the global region with both augmentations in the one-way mode or with terrain information in the two-way mode of operation. For the south pole region, all other constellations except the Lang-Meyer version 2 provide the 90-percent system availability after the 15-min integration period with both augmentations in the one-way mode or with terrain information in the two-way mode of operation. Lang-Meyer version 2 provides the 90-percent system availability after the 1-hr integration period in the south pole region with the same augmentation combinations.

System latency results.—The results provided in appendix C.2.1 to C.2.4 for the 90-percent system availability case and in appendix C.2.5 to C.2.8 for the 99-percent system availability case reveal the same trends that were seen in the system availability analysis and in the system latency analysis for the 5° minimum elevation angle. In general, latency to reach the minimum system availability decreases for a given constellation as the various augmentations are added and also as the number of satellites in the constellation increases. One case that is outside this general trend is that of the hybrid elliptical constellation, which is outperformed by the polar 6/2/1 and the inclined 6/2/0 constellations, both of which have six satellites as compared with the hybrid elliptical that has seven satellites. Another trend consistent with previous analyses is that adding terrain information reduces system latency and transitioning from one-way mode to two-way mode of operation also reduces system latency.

The differences in the system latencies between the 5° and 10° minimum elevation angles should be noted. For example, in the 5° minimum elevation angle case in the one-way mode without terrain information in the global region, the latency for the polar 6/2/1 is 29.39 min for the 90-percent system availability and 38.95 min for the 99-percent system availability. However, under these same operating modes but with a 10° minimum elevation angle, the latency is 39.41 min for the 90-percent system availability and 53.41 min for the 99-percent system availability. Similarly, when comparing with the inclined 6/2/0 constellation, the latencies were 51.64 min for the 90-percent system availability and 114.64 min for the 99-percent system availability under the 5° minimum elevation angle. However, under the 10° minimum elevation angle, the system latencies are 76.58 min for the 90-percent system availability and 147.40 min for the 99-percent system availability. These results show that not all constellations are affected by the transition from the 5° to the 10° minimum elevation angle in the same way. Also, not all constellations are affected similarly when the minimum system availability requirement goes from 90 percent to 99 percent. More comparisons can be made from the data in appendix C.2 for the 10° minimum elevation angle.

Failure system latency results.—Results for the failure system latency analysis for the 10° elevation angle are also presented in appendix C.2.1 to C.2.4 for the 90-percent system availability case and in appendix C.2.5 to C.2.8 for the 99-percent system availability case. For the 90-percent system availability case, increases in weighted system latency for the one-way mode of operation without terrain information in the global region ranged from 0 min (polar 12/4/1) to about 15 min (polar 8/2/1) and to between 44 to 94 min for the remaining constellations. However, for the 99-percent system availability case, increases in weighted system latency with the same augmentation scheme in the global region ranged from 10 min (polar 12/4/1) to between 51 to 231 min with the polar 6/2/1 having the largest increase in weighted system latency of 230.13 min. This analysis shows that increasing the system availability requirement to 99 percent has a more profound effect when one satellite is unavailable for the polar 6/2/1 than for any other constellation when in the single failure mode. One other interesting result is that the increase for the polar 8/2/1 in the above described augmentation scheme in the global region is less than that for the same scheme with a 5° minimum elevation angle. This result is attributed to the failure mode latency already being over 10 min larger with the 10° minimum elevation angle than with the 5° minimum elevation angle.

For the system in two-way mode of operation with terrain information for the global region, all constellations except the Lang-Meyer and the inclined 5/5/1 had weighted system latency increases of less than 4 min at the 90-percent system availability requirement. The Lang-Meyer and inclined 5/5/1 had weighted system latency increases in the range of 18 to 20 min. However, when requiring a 99-percent system availability, increases in weighted system latency ranged from 0 min (polar 12/4/1) to up to 232 min. The polar 6/2/1 had an increase of 107.35 min when requiring a 99-percent system availability, but only 3.66 min for the 90-percent system availability. Many more comparisons similar to these can be made from the data in appendix C.2.

Minimum Surface Elevation Angle of 15°

This section presents the nonfailure mode and failure mode system availability and system latency results for surface points requiring a minimum elevation angle of 15°. Illustrations of the results and tabulated data per region can be found in appendix B.3 for system availability analyses results and in appendix C.3 for system latency analyses results.

System availability results.—Figure 5 shows the stoplight chart of the performance of each of the systems proposed in this report in terms of the latency required to achieve 90-percent system availability over a specified region of the surface of the Moon. The same trend was observed here as was observed for the system availability analysis results presented previously for the 5° and 10° elevation angles: latency improves as augmentations are added to the system. In the global region, the general trend is for two-way mode operation with terrain information to outperform one-way and two-way modes of operation without terrain information. The sensitivity to latency on the number of orbiters is not visible because not all the points have continuous access to a satellite at the 15° elevation angle.

Results for the 15° minimum elevation angle (app. B.3) can be compared with the results for the 5° and 10° minimum elevation angles shown in appendixes B.1 and B.2, respectively. From comparing figure 5 (15°) with figure 1 (5°) and with figure 3 (10°), it is clear that there is degradation in performance with the increase in the minimum elevation angle to 15°. This degradation is due to the loss of visibility when the satellite elevation angle to the surface point is between 10° and 15°. For example, in the global region when operating in the one-way mode without terrain information, only the polar

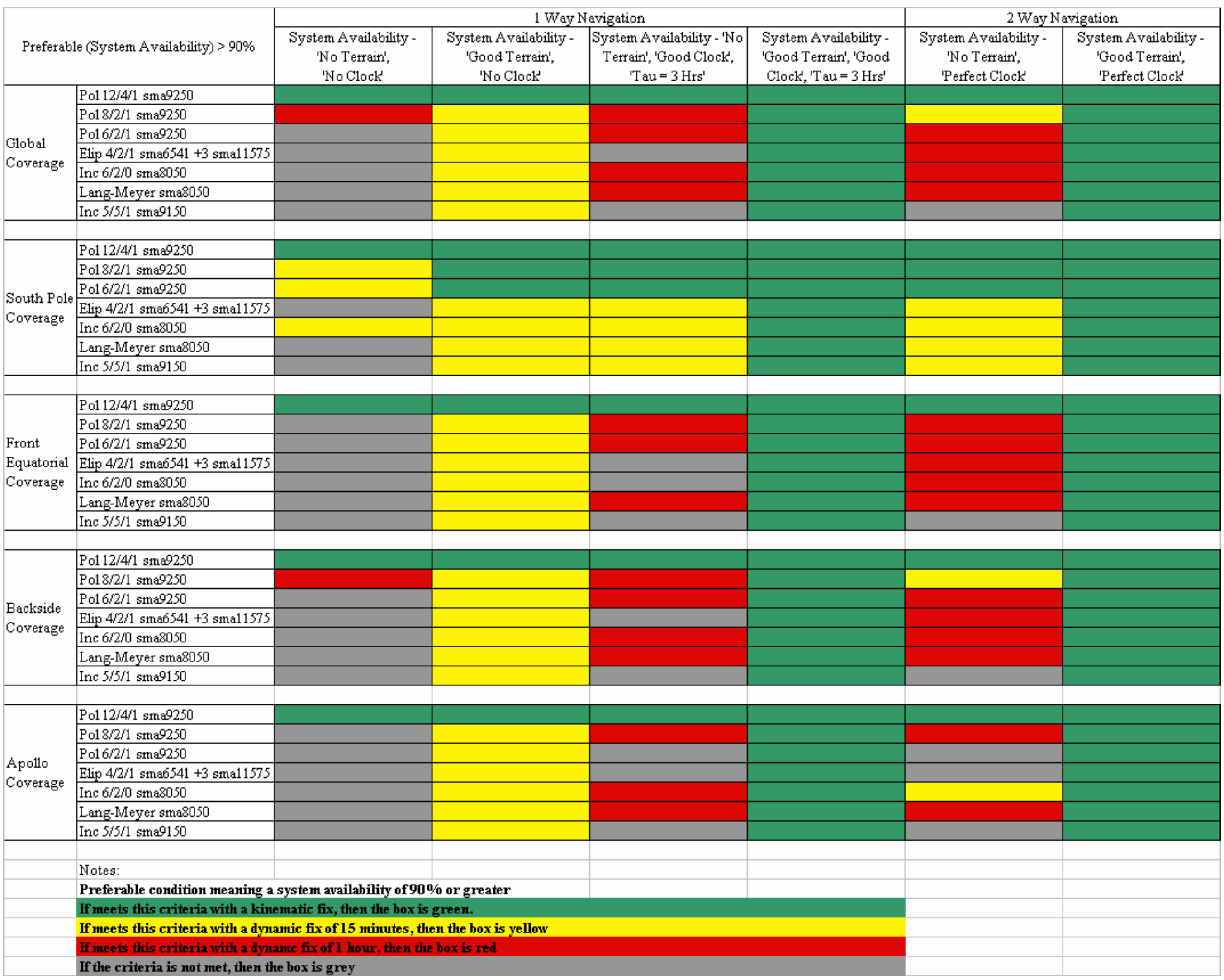

Figure 5.—Stoplight chart for system availability results at 15° elevation angle.

12/4/1 constellation can provide kinematic solutions with a system availability of 90 percent. The polar 8/2/1 now requires the 1-hr integration period to meet the 90-percent system availability for the same operating mode. No other constellations can meet the 90-percent system availability within the 1-hr integration. The closest constellation to the 90-percent system availability after the 1-hr integration period is the hybrid elliptical with a weighted system availability of 84.97 percent.

When in the two-way mode of operation without terrain information for the front equatorial region, only the polar 12/4/1 can meet the 90-percent system availability with kinematic solutions, whereas the remaining constellations (except the inclined 5/5/1) can meet the 90-percent system availability with the 1-hr integration period. Previously herein, with the 10° minimum elevation angle, the polar 8/2/1 could also meet the 90-percent system availability with a 15-min dynamic solution, which shows the effect of raising the minimum elevation angle to 15°.

Failure system availability results.—Figure 6 shows the stoplight chart of the performance of each of the systems proposed in this report in terms of the latency required to achieve 90-percent system availability over a specified region of the surface of the Moon for the single-mode failure constellations. The total loss of one satellite for the 15° minimum elevation angle resulted in all constellations having discontinuous coverage. This results in sensitivity to the number of orbiters in the constellation not being as important a factor. As in the case for the 5° and 10° minimum elevation angles, there are interesting results for constellations with more than one failure mode, as in the hybrid elliptical and the Lang-Meyer. The various failure modes for those constellations do not perform the same, so if there were a failure in one of the satellites in the constellations, it would be better in terms of system performance for the constellation to be in the hybrid elliptical version 2 or version 3 mode (note that the only difference is in the south pole region) and in the Lang-Meyer version 2 mode (except in the south pole region, where version 1 performs better).

It is also important to note the degradation that occurs when the minimum elevation angle is increased from 10° to 15° in the failure mode of operation. In the tables presented in appendix B.3, it can be shown that the losses in weighted system availability may not be as large for some constellations (e.g., hybrid elliptical and polar 6/2/1) as they are for others (e.g., polar 12/4/1) in comparison with the losses in failure system availability for the 10° minimum elevation angle. This is an artifact of the losses in system availability that occur when transitioning from 5° to 10° minimum elevation angle.

In the failure mode of operation, the only constellation that can provide kinematic solutions with a system availability of at least 90 percent without any augmentations is the polar 12/4/1. The polar 8/2/1 (with no augmentations in one-way mode) can meet the 90-percent system availability in the south pole region with a 1-hr integration period dynamic solution. All other constellations do not provide 90-percent system availability in any region with no augmentations in the one-way mode within the 1-hr integration period. For the south pole region, all other constellations except the Lang-Meyer version 2 provide the 90-percent system availability after the 1-hr integration period with terrain information in the one-way mode. Lang-Meyer version 2 does not provide the 90-percent system availability after the 1-hr integration period in the south pole region with terrain information in the two-way mode of operation. For the global region operating in the one-way mode with clock synchronization, only the polar 12/4/1 can provide the 90-percent system availability kinematically. The polar 8/2/1 can provide the 90-percent system availability after a 1-hr integration period, but all other constellations do not meet the 90-percent system availability within the 1-hr integration period.

System latency results.—The results provided in appendix C.3.1 to C.3.4 for the 90-percent system availability case and in appendix C.3.5 to C.3.8 for the 99-percent system availability case reveal the same trends that were seen in the system availability analysis and the system latency analysis for the 5° and 10° minimum elevation angle. In general, latency to reach the minimum system availability decreases for a given constellation as the various augmentations are added and also as the number of satellites in the constellation increases. One case outside this general trend is that of the hybrid elliptical constellation, which is outperformed by the polar 6/2/1, the inclined 6/2/0, and the Lang-Meyer constellations, all of which have six satellites as compared with the hybrid elliptical that has seven satellites. The final trend consistent with previous analyses is that adding terrain information reduces system latency and transitioning from one-way mode to two-way mode of operation also reduces system latency.

It is also important to discuss the differences in the system latencies between the 5°, 10°, and 15° minimum elevation angles. For example, for the polar 6/2/1 constellation operating in the one-way mode without terrain information in the global region for the 90-percent system availability, the system latencies go from 29.39 min for 5°, to 39.41 min for 10°, and to 51.03 min for 15°; for the 99-percent system availability, the system latencies go from 38.95 min for 5°, to 53.41 min for 10°, and to 71.11 min for 15°. Similarly, for the inclined 6/2/0 constellation for the 90-percent system availability, the system latencies go from 51.64 min for 5°, to 76.58 min for 10°, and to 101.87 min for 15°; for the 99-percent system availability, the system latencies go from 114.64 min for 5°, to 147.40 min for 10°, and to 172.67 min for 15°. These results demonstrate that not all constellations are affected similarly when the minimum system availability requirement goes from 90 to 99 percent. More comparisons can be made from the data in appendix C.3 for the 15° minimum elevation angle.

Failure system latency results.—Results for the failure system latency analysis for the 15° minimum elevation angle are also shown in appendix C.3.1 to C.3.4 for the 90-percent system availability case and in appendix C.3.5 to C.3.8 for the

99-percent system availability case. For the 90-percent system availability case, increases in weighted system latency for the one-way mode of operation without terrain information in the global region ranged from about 0 min (polar 12/4/1) to about 15 min (polar 8/2/1) to between 34 to 122 min for the remaining constellations. However, for the 99-percent system availability case, increases in weighted system latency with the same augmentation scheme in the global region ranged from 33 min (polar 12/4/1) to between 40 to 280 min, with the polar 6/2/1 having the second largest increase in weighted system latency of 265.05 min. These results show that increasing the system availability requirement to 99 percent has a more profound effect when one satellite is unavailable for the polar 6/2/1 than any other constellation has except for the hybrid elliptical version 3 when in the single failure mode.

With the system in two-way mode of operation with terrain information for the global region, all constellations except the inclined 5/5/1 had weighted system latency increases of less

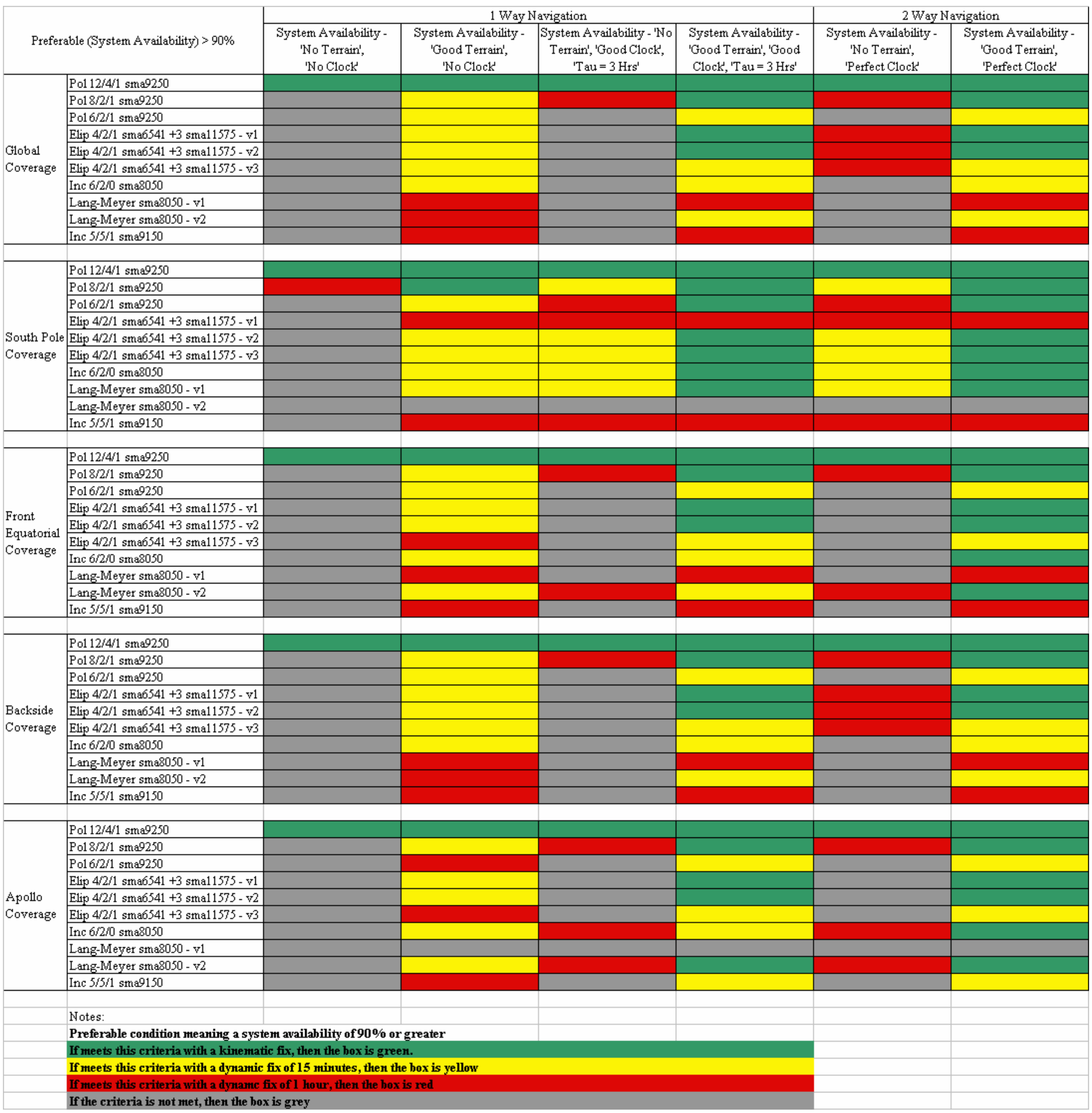

Figure 6.—Stoplight chart for failure system availability results at 15° elevation angle.

than 20 min at the 90-percent system availability requirement. The inclined 5/5/1 had a weighted system latency increase of 51.59 min, so that the total latency for the inclined 5/5/1 in the global region was 129.54 min. However, when requiring a 99-percent system availability, increases in weighted system latency ranged from just over 0 min (polar 12/4/1) to up to 319 min. The polar 6/2/1 had an increase of 160.24 min when requiring a 99-percent system availability (total latency of 244.85 min), but only had an increase of 13.30 min for the 90-percent system availability (total latency of 13.30 min). Many more comparisons can be made from the data presented in appendix C.3.

Conclusions

Generalized DoP allows the effects of multiple radiometric measurements to be assessed in the same manner that standard measures of DoP are used. In the current case, the effect of integrating multiple radiometric measurements in time is assessed to allow the performance of sparse constellations around the Moon to be compared with fully populated constellations that provide only kinematic solutions. With this innovation, the basis of comparison can be changed to a domain that is more closely aligned with user requirements, namely, the latency associated with achieving a particular level of precision in the state estimate.

The restriction to the use of kinematic solutions, as is done with an analysis based on static DoP, biases the selection of a constellation to those with more satellites. The use of dynamic solutions permits integrating radiometric signals over a period of time to improve the system availability and thus allows for the consideration of constellations with fewer satellites. The application of generalized DoP for the evaluation of inherent navigation capability of constellations of orbiting spacecraft around the Moon has thereby eliminated this bias. The analysis method described herein has thus made possible setting forth recommendations for the buildup of a Moon-orbiting sparse constellation of spacecraft.

Inspection of the result summaries reveals a general trend over all identified lunar regions that the performance of the kinematic system is significantly improved by the prescribed augmentations. In general, system latency decreases for a given constellation as the augmentations are added. In particular, although using a highly stable clock for the user receiver brings about an improvement in performance, the improvement in performance brought about by the knowledge of user altitude alone is significantly greater than that brought about by a stable user clock. Additionally, note that using a stable user clock together with knowledge of user altitude provides significant improvements over knowledge of user altitude alone. Thus, the two pieces of information appear to be uncorrelated. Also, increasing the minimum user elevation angle requirement severely degraded the performance of most of the constellations, the exception being the polar 12/4/1. Finally, changing the mode of operation of the constellation into failure mode also severely degraded the performance of the constellations, with some constellations experiencing a more severe degradation than others, such as the hybrid elliptical version 3.

The polar 12/4/1 lunar constellation offers ideal performance from a navigation-only perspective, although it is over specified when communication considerations are taken into account. When both navigation and communications are taken into account, however, the polar 8/2/1 is the desired constellation. There is roughly a tie in the performance of the polar 6/2/1, the elliptical 4/2/1 + 3, and the inclined 6/2/0. The selection of the constellation may be based on the desired type of missions, as there are regional differences in coverage.

Based on global coverage, two constellations are candidates for further study. The polar 6/2/1 constellation has the smallest number of satellites capable of providing low-latency (15-min) position fixes. This constellation also represents a scalable solution since a second 6/2/1 constellation can be added to the first to create a 12/4/1 without reconfiguring the first. The ability for a kinematic solution obtained by the polar 8/2/1 in a two-way or a one-way system with augmentations in the global region would be useful in an emergency situation where the astronauts would need to have immediate navigation information. It adds significant robustness because a polar 8/2/1 constellation can easily be reconfigured to a polar 6/2/1 in the event of a failure of one or two satellites, if the failures occur in separate planes.

Appendix A—Lunar Constellations

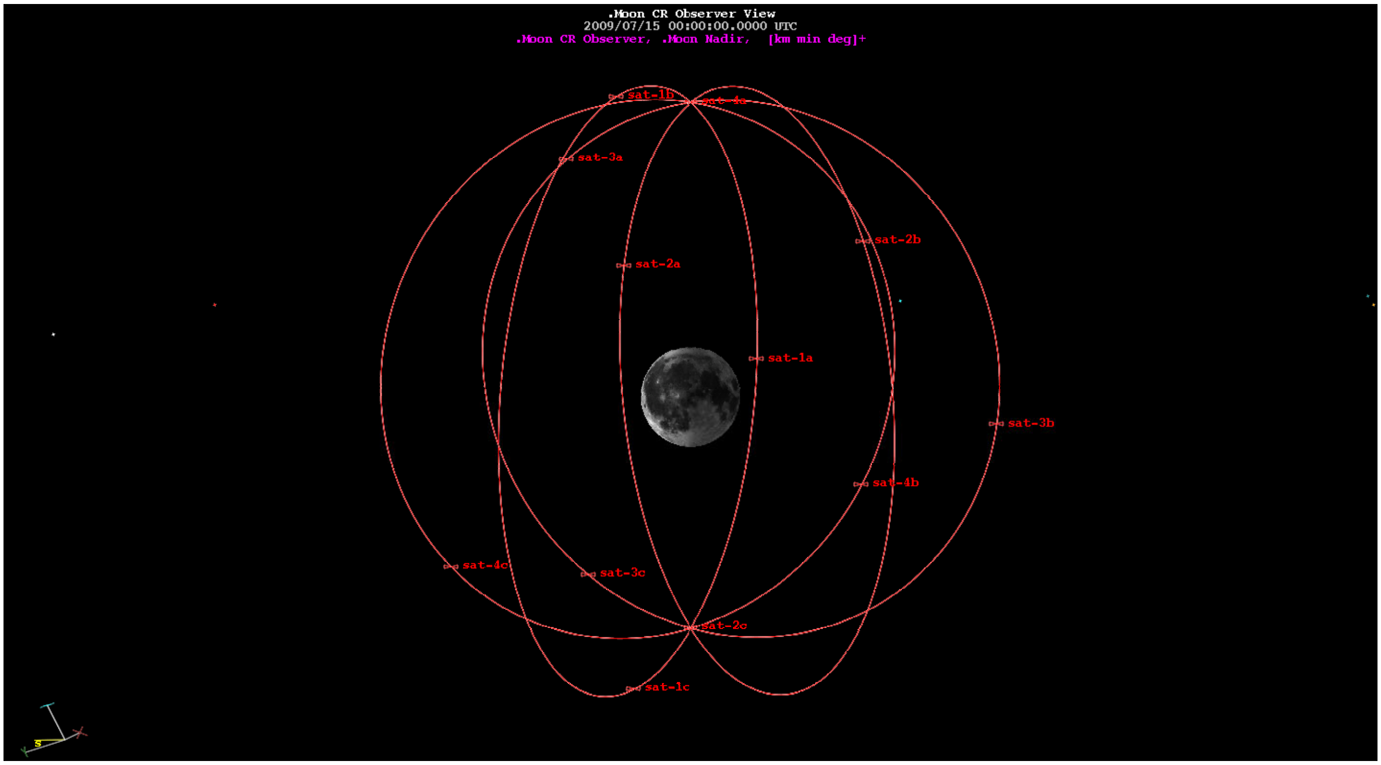

Figure A.1.—Polar 12/4/1; SMA, 9250.

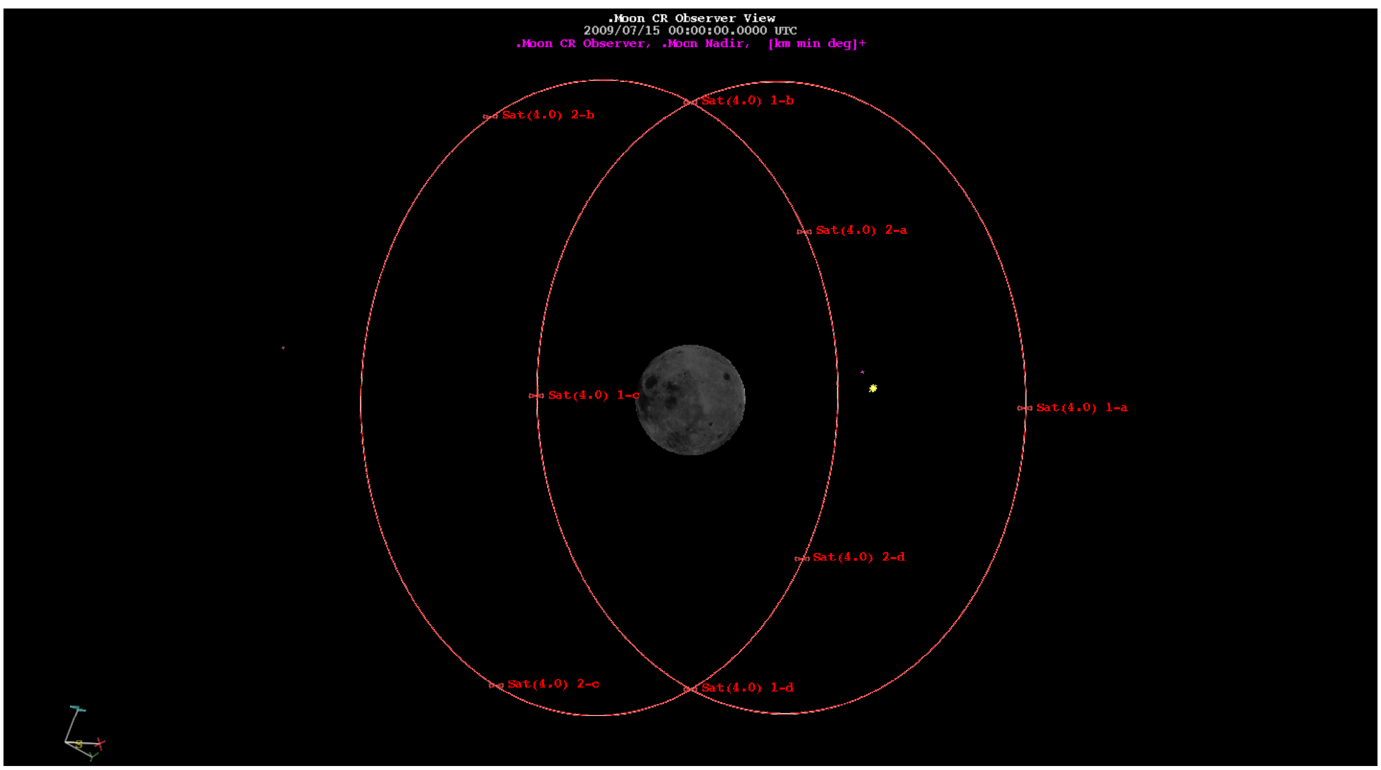

Figure A.2.—Polar 8/2/1; SMA, 9250.

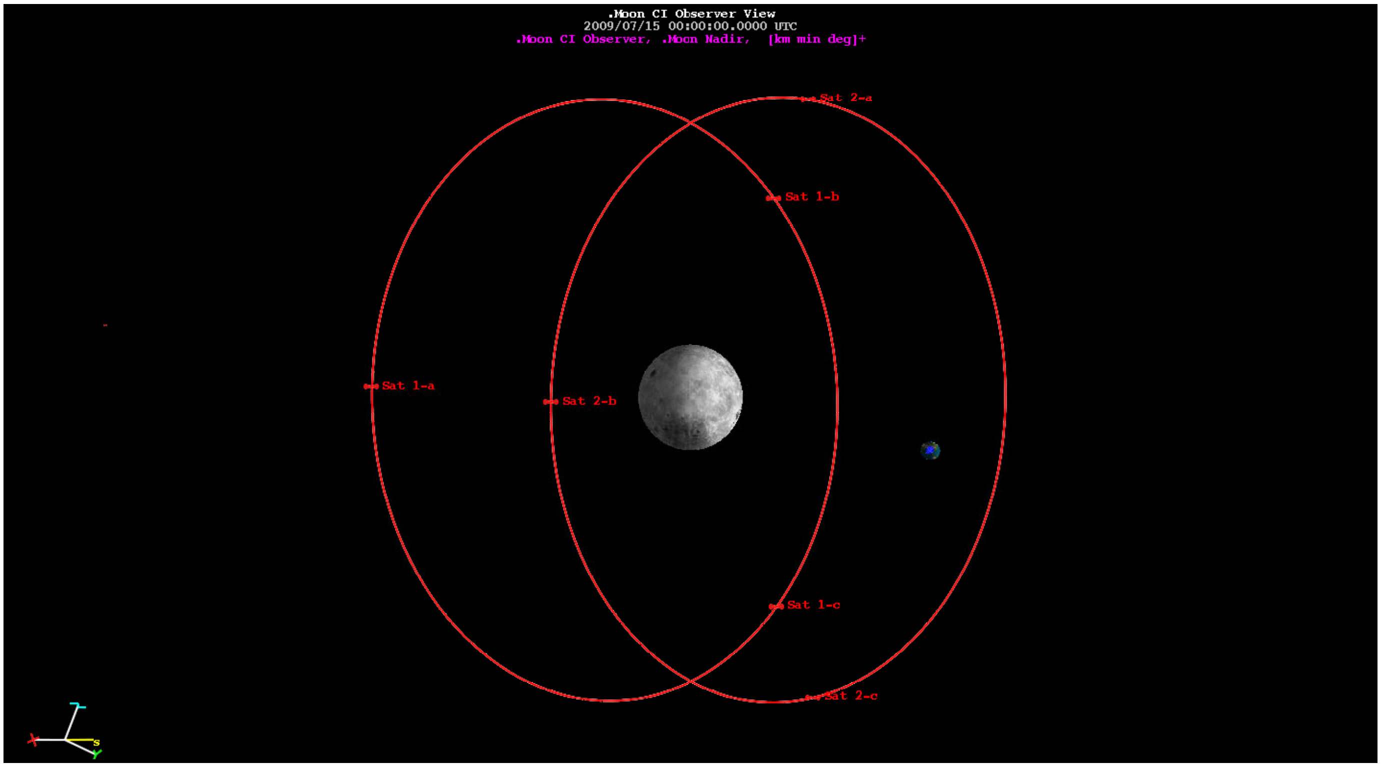

Figure A.3.—Polar 6/2/1; SMA, 9250.

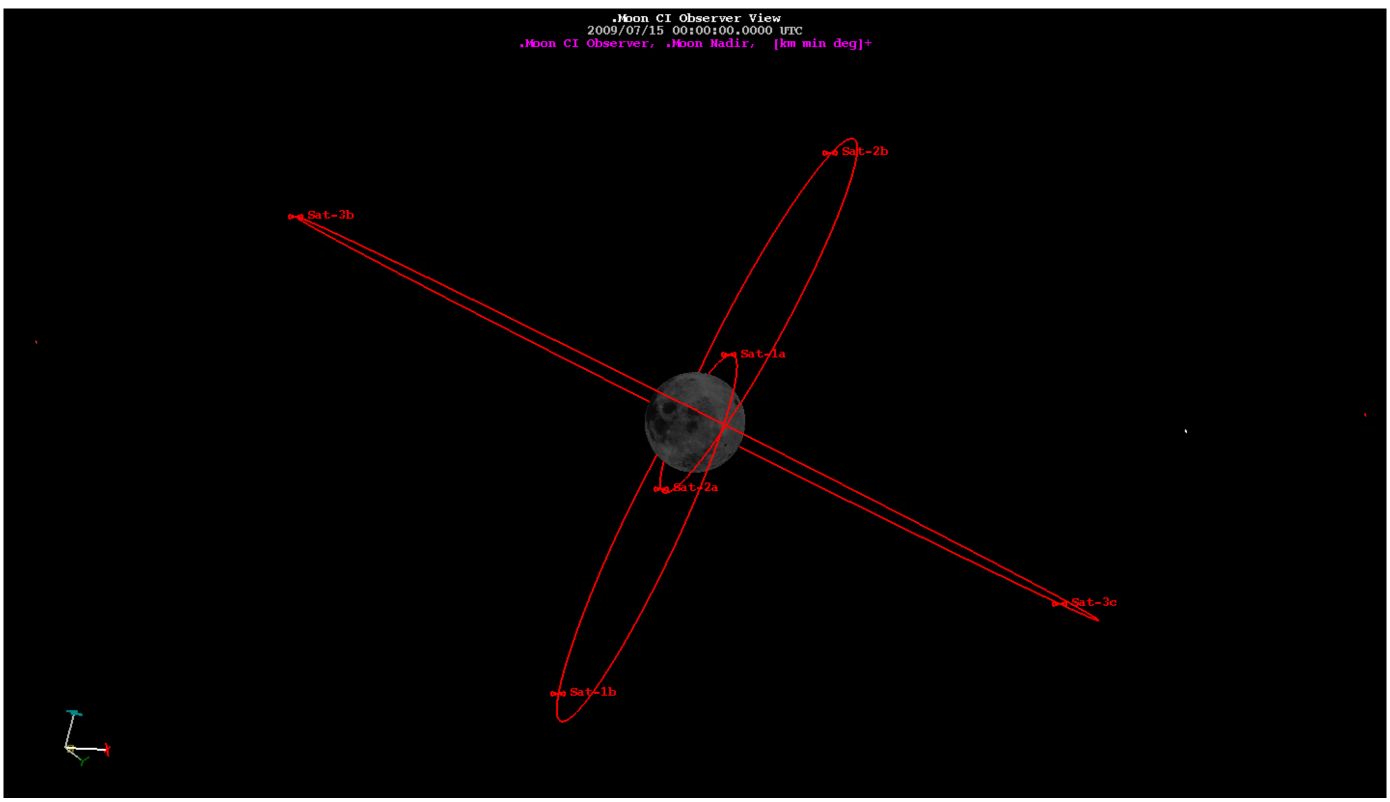

Figure A.4.—Hybrid elliptical 4/2/1; SMA, 6541 + 3; SMA, 11575.

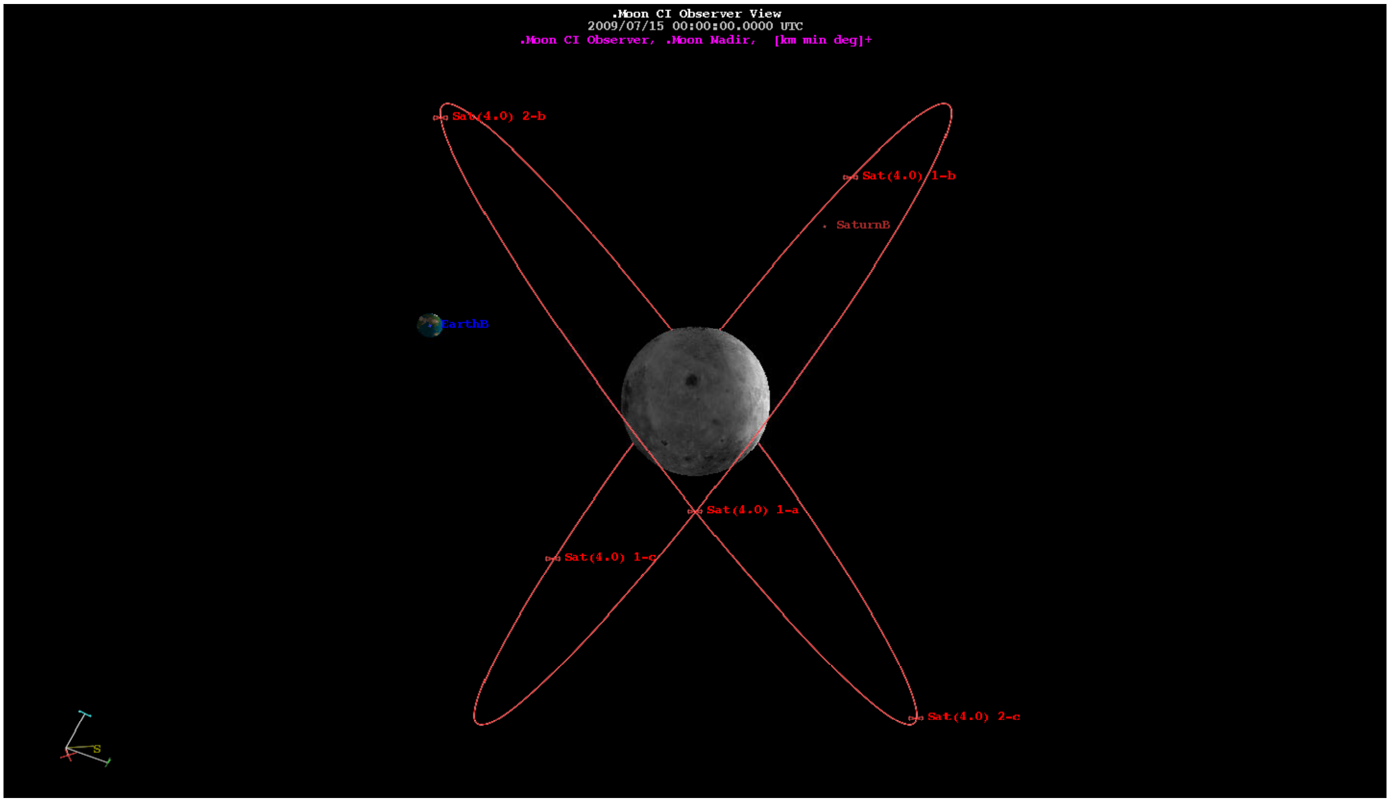

Figure A.5.—Inclined 6/2/0; SMA, 8050.

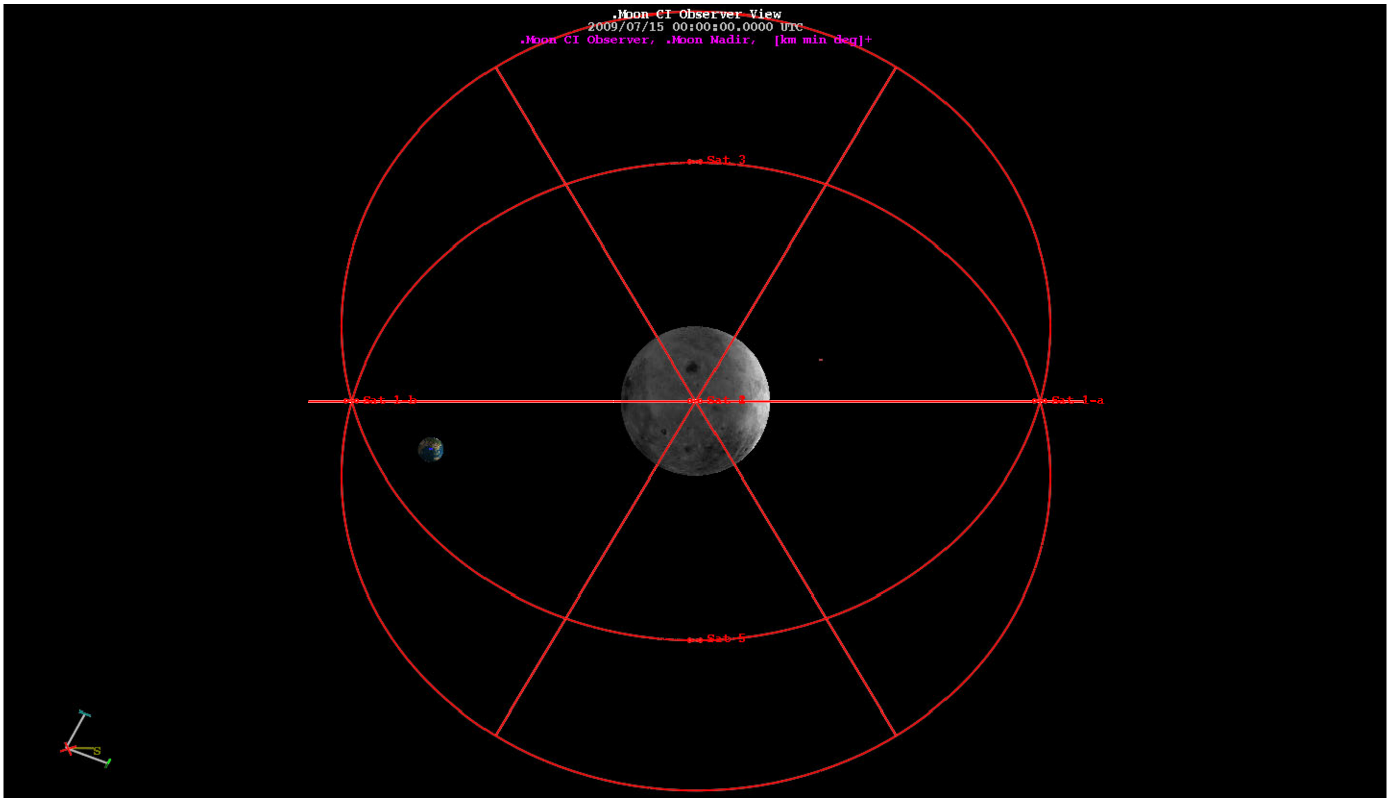

Figure A.6.—Lang-Meyer 4/4/1 + 2; SMA, 8050.

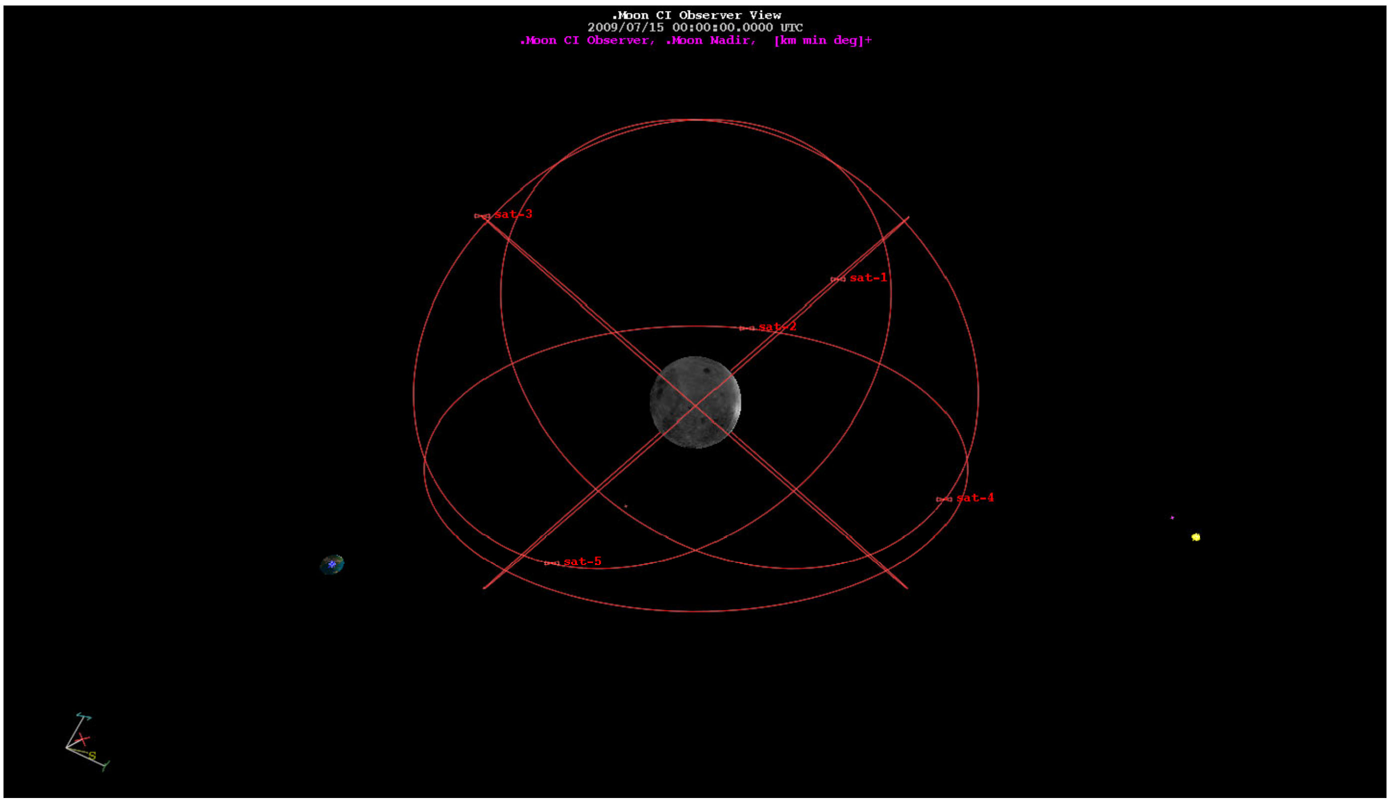

Figure A.7.—Inclined 5/5/1; SMA, 9150.

Appendix B—System Availability/Failure System Availability Results

B.1 User Minimum Elevation Angle of 5°

***B.1.1 No terrain, no clock, one-way kinematic*.**—Figure B.1.1.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with kinematic measurements). Table B.1.1.1 tabulates the weighted system availabilities from figure B.1.1.1. Table B.1.1.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

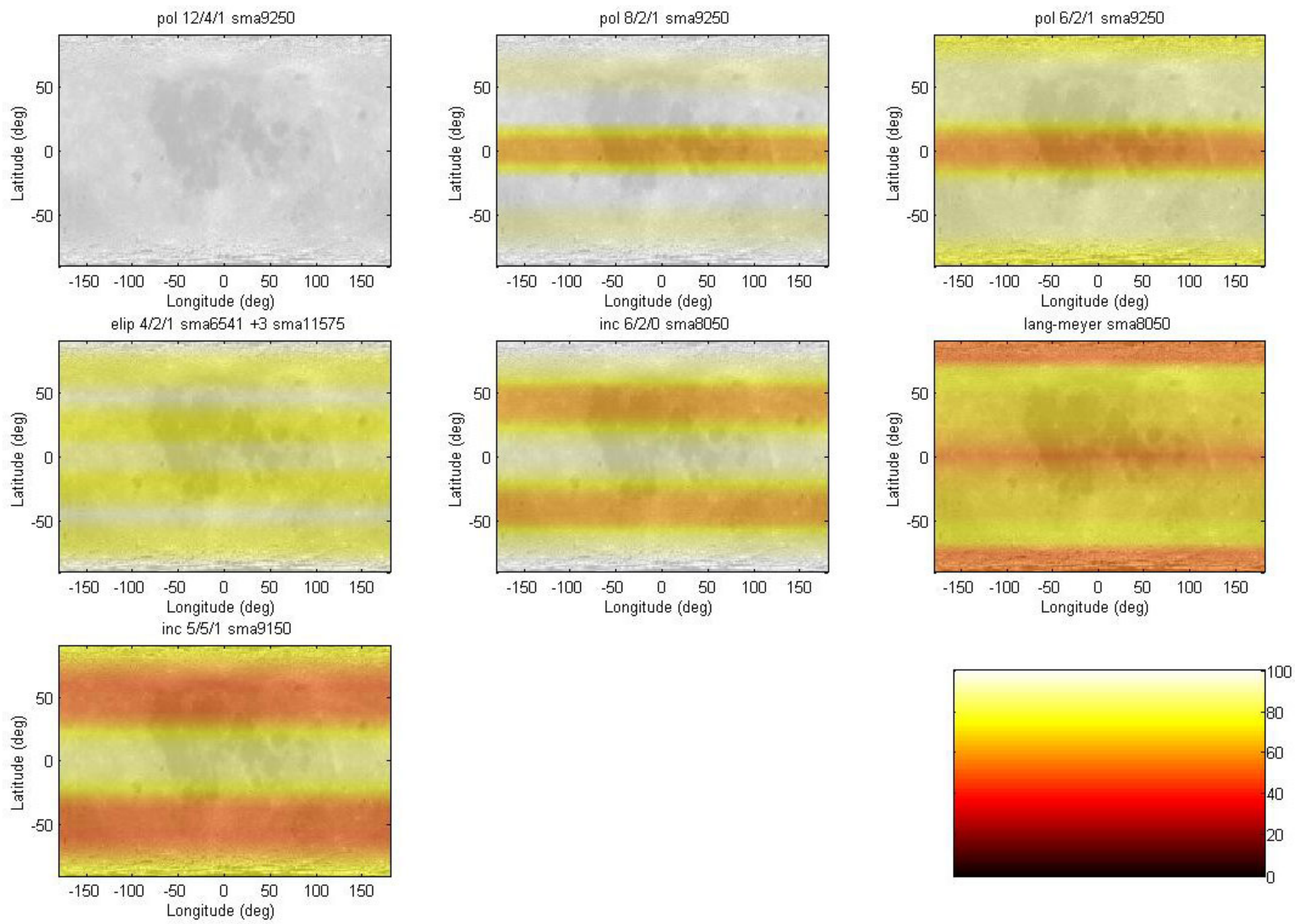

Figure B.1.1.1.—Lunar system availability results.

TABLE B.1.1.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.95	100.00	99.94	99.95	99.92
Pol 8/2/1 SMA 9250	87.32	100.00	85.47	87.33	81.15
Pol 6/2/1 SMA 9250	79.02	75.86	76.40	79.01	71.44
Elip 4/2/1 SMA 6541 + 3 SMA 11575	81.29	92.87	81.03	81.24	78.88
Inc 6/2/0 SMA 8050	75.96	99.00	74.92	75.97	80.26
Lang-Meyer SMA 8050	66.18	52.16	65.39	66.19	64.05
Inc 5/5/1 SMA 9150	66.09	73.14	69.93	66.12	76.58

TABLE B.1.1.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.17	0.00	0.23	0.17	0.31
Pol 8/2/1 SMA 9250	11.76	10.92	12.25	11.74	12.06
Pol 6/2/1 SMA 9250	22.45	17.10	22.13	22.39	21.04
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	13.57	23.12	13.80	13.57	13.26
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	13.59	0.40	13.78	13.62	13.28
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	18.94	26.59	18.22	18.82	17.02
Inc 6/2/0 SMA 8050	22.15	30.36	21.66	22.24	23.30
Lang-Meyer SMA 8050 - v1	25.98	0.00	30.26	25.80	31.10
Lang-Meyer SMA 8050 - v2	11.79	25.75	9.67	11.82	8.56
Inc 5/5/1 SMA 9150	22.67	28.75	24.00	22.73	26.53

B.1.2 No terrain, no clock, one-way dynamic (15 min).—Figure B.1.2.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with 15-min dynamic measurements). Table B.1.2.1 tabulates the weighted system availabilities from figure B.1.2.1. Table B.1.2.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

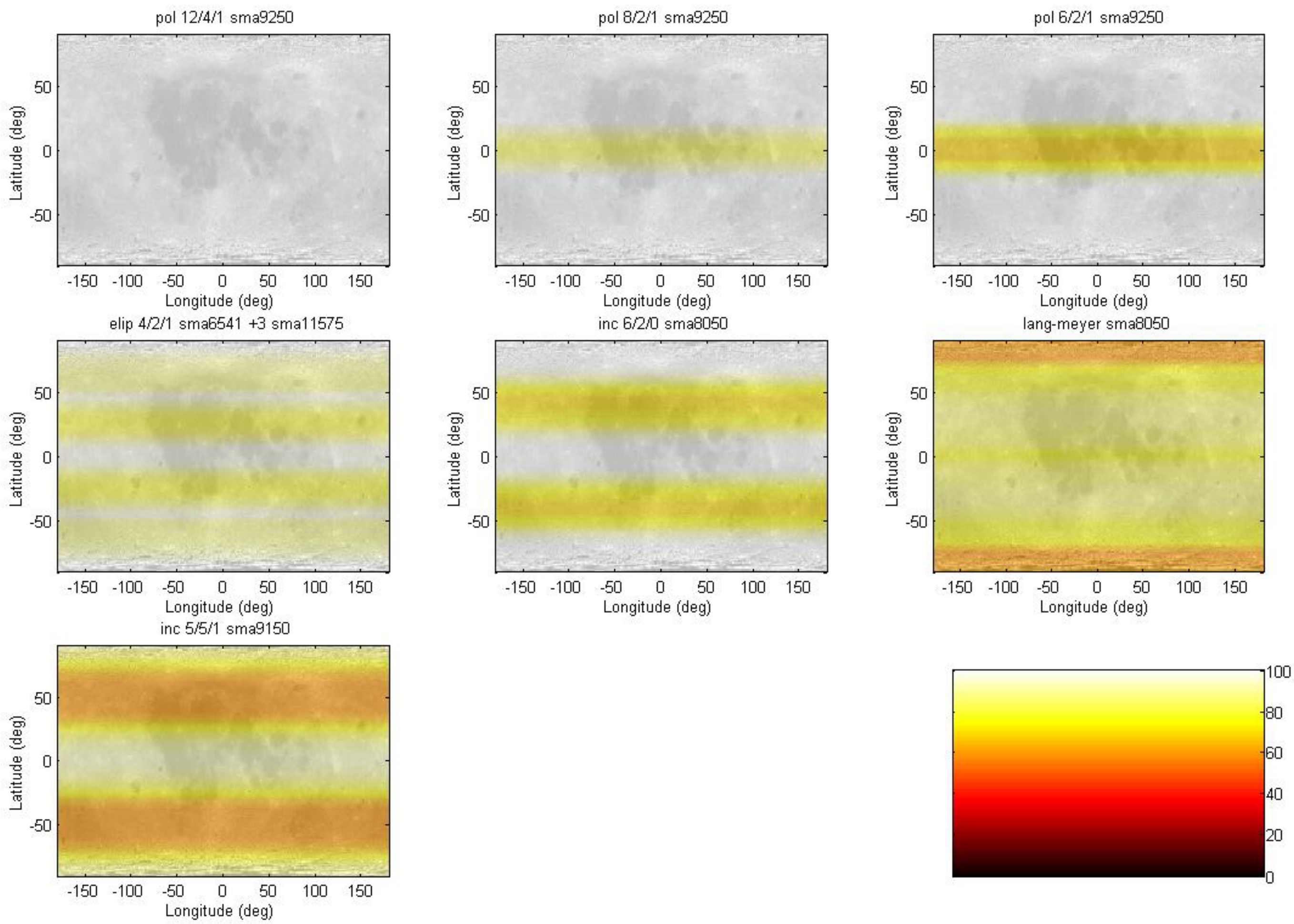

Figure B.1.2.1.—Lunar system availability results.

TABLE B.1.2.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	96.22	100.00	94.98	96.22	93.22
Pol 6/2/1 SMA 9250	90.69	100.00	87.64	90.69	83.25
Elip 4/2/1 SMA 6541 + 3 SMA 11575	88.73	97.90	88.41	88.73	87.29
Inc 6/2/0 SMA 8050	85.41	100.00	84.01	85.41	89.01
Lang-Meyer SMA 8050	81.57	59.85	84.32	81.56	84.03
Inc 5/5/1 SMA 9150	73.46	85.99	76.59	73.48	83.01

TABLE B.1.2.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.03	0.00	0.04	0.03	0.05
Pol 8/2/1 SMA 9250	7.65	7.30	7.82	7.56	8.22
Pol 6/2/1 SMA 9250	22.42	23.89	21.76	22.38	21.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	11.97	17.70	12.07	11.95	12.19
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	11.97	0.39	12.02	11.99	12.05
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	13.00	11.83	13.10	12.93	12.00
Inc 6/2/0 SMA 8050	23.45	27.43	22.77	23.54	23.96
Lang-Meyer SMA 8050 - v1	16.10	0.00	17.28	15.99	14.42
Lang-Meyer SMA 8050 - v2	15.43	29.57	15.02	15.48	14.09
Inc 5/5/1 SMA 9150	24.09	32.69	25.00	24.13	27.31

***B.1.3 No terrain, no clock, one-way dynamic (1 hr)*.**—Figure B.1.3.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with 1-hr dynamic measurements). Table B.1.3.1 tabulates the weighted system availabilities from figure B.1.3.1. Table B.1.3.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

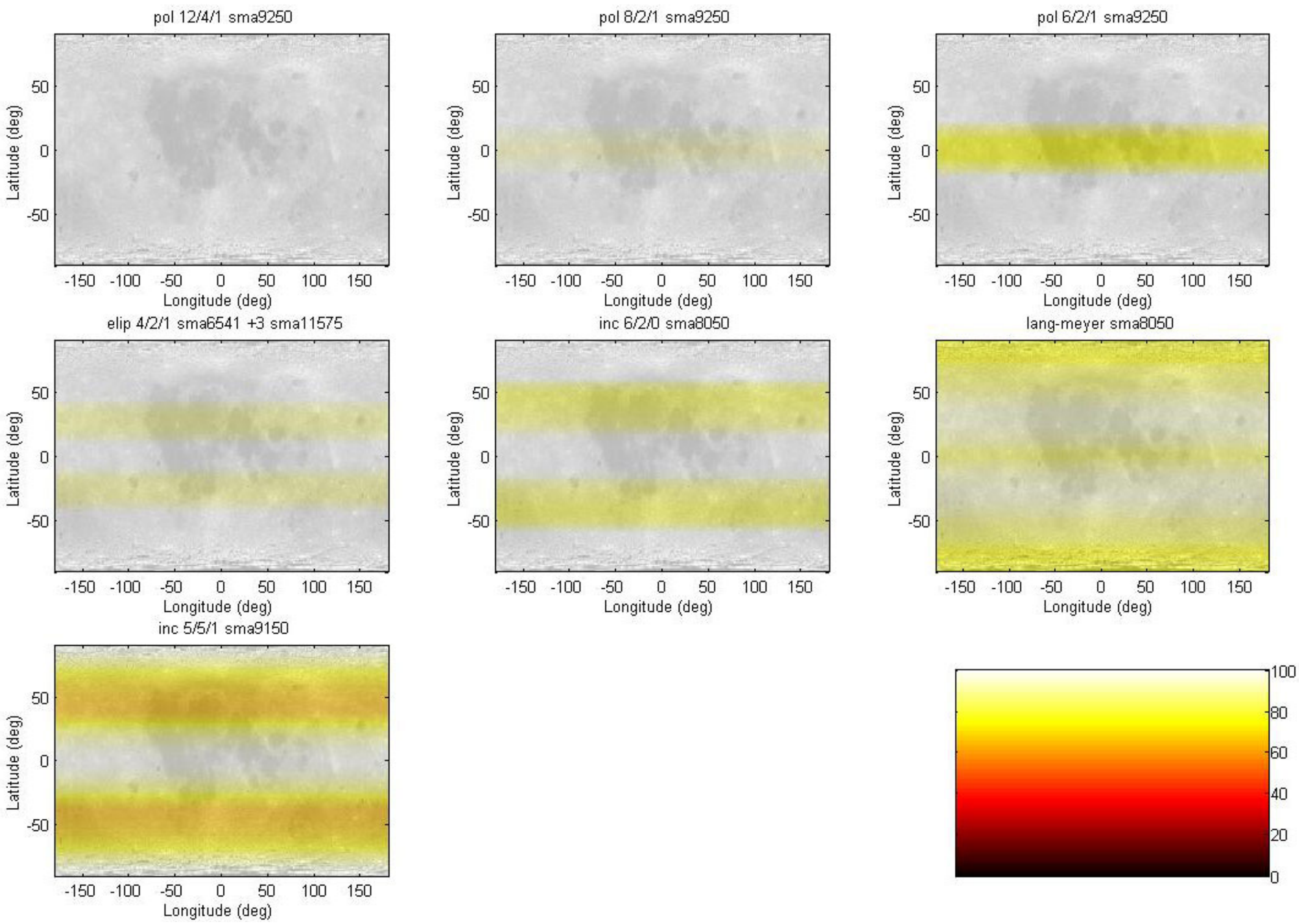

Figure B.1.3.1.—Lunar system availability results.

TABLE B.1.3.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	98.41	100.00	97.89	98.41	97.15
Pol 6/2/1 SMA 9250	93.20	100.00	90.98	93.21	87.77
Elip 4/2/1 SMA 6541 + 3 SMA 11575	95.60	99.84	94.43	95.59	93.89
Inc 6/2/0 SMA 8050	92.04	100.00	91.07	92.04	94.05
Lang-Meyer SMA 8050	89.15	76.51	91.52	89.14	91.42
Inc 5/5/1 SMA 9150	80.02	95.28	82.09	80.03	88.13

TABLE B.1.3.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	3.44	0.00	4.21	3.43	5.21
Pol 6/2/1 SMA 9250	15.97	8.45	17.09	15.93	17.21
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	7.26	5.34	6.45	7.23	6.67
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	7.23	0.34	6.40	7.22	6.51
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	6.62	2.54	7.32	6.60	7.33
Inc 6/2/0 SMA 8050	16.43	19.89	16.42	16.51	15.99
Lang-Meyer SMA 8050 - v1	15.56	0.00	17.03	15.46	14.57
Lang-Meyer SMA 8050 - v2	13.33	37.85	12.32	13.37	11.12
Inc 5/5/1 SMA 9150	23.00	33.29	23.00	23.01	24.78

***B.1.4 Good terrain, no clock, one-way kinematic*.**—Figure B.1.4.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with kinematic measurements). Table B.1.4.1 tabulates the weighted system availabilities from figure B.1.4.1. Table B.1.4.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

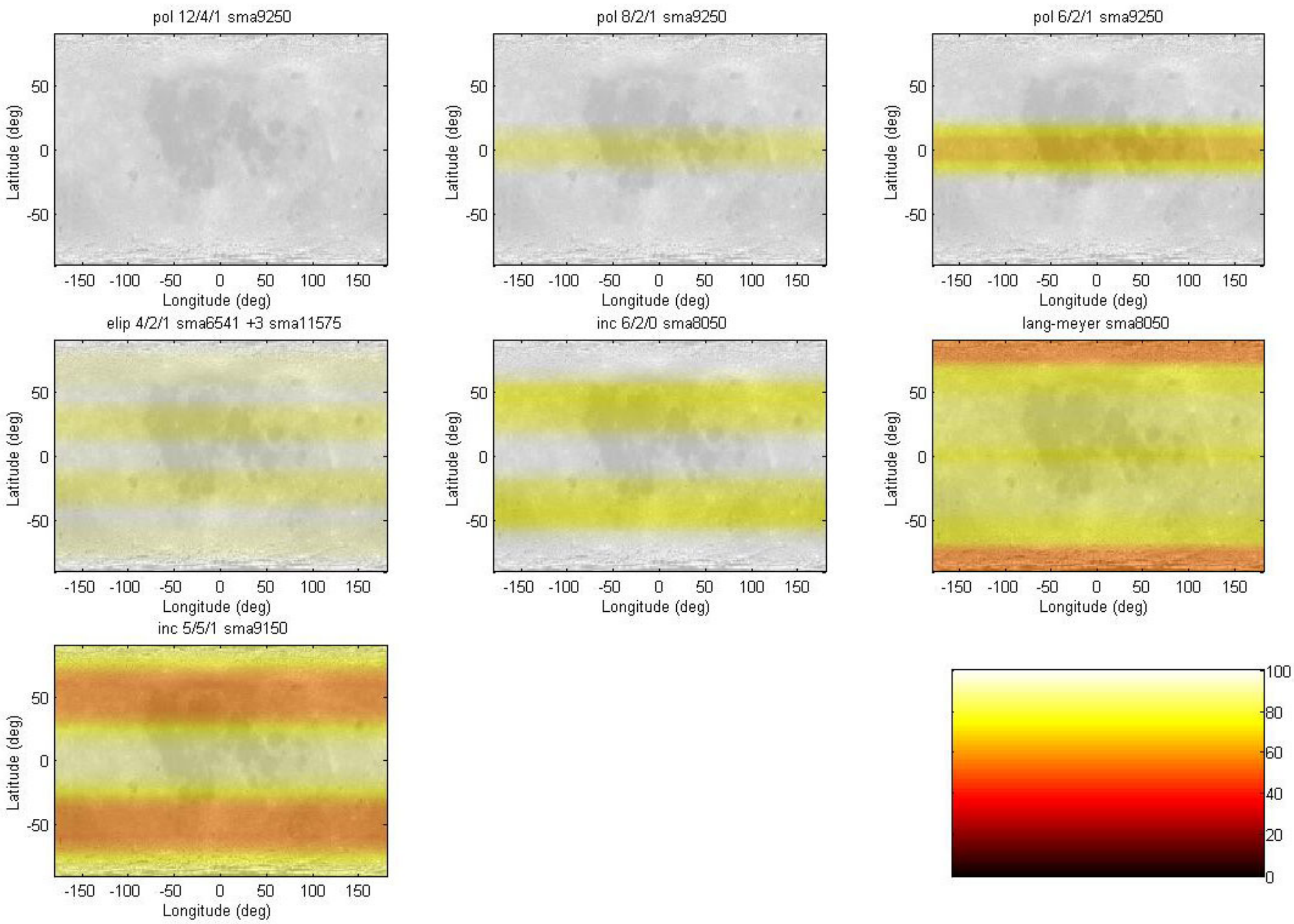

Figure B.1.4.1.—Lunar system availability results.

TABLE B.1.4.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	96.51	100.00	95.37	96.51	93.75
Pol 6/2/1 SMA 9250	90.00	100.00	86.73	90.00	82.02
Elip 4/2/1 SMA 6541 + 3 SMA 11575	91.37	97.61	90.58	91.37	89.57
Inc 6/2/0 SMA 8050	87.30	100.00	86.30	87.30	90.20
Lang-Meyer SMA 8050	78.48	54.30	81.28	78.47	81.10
Inc 5/5/1 SMA 9150	70.91	82.12	74.38	70.94	80.89

TABLE B.1.4.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.05	0.00	0.06	0.05	0.08
Pol 8/2/1 SMA 9250	6.03	0.08	6.81	6.01	7.65
Pol 6/2/1 SMA 9250	21.10	17.35	21.63	21.06	21.19
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	11.16	21.57	10.15	11.14	9.91
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	11.13	0.36	10.07	11.14	9.69
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	14.53	11.75	15.59	14.46	15.63
Inc 6/2/0 SMA 8050	21.92	25.59	21.48	22.01	22.07
Lang-Meyer SMA 8050 - v1	16.04	0.00	17.04	15.91	14.24
Lang-Meyer SMA 8050 - v2	15.92	26.81	15.68	15.98	14.98
Inc 5/5/1 SMA 9150	24.18	31.86	25.37	24.23	27.83

B.1.5 Good terrain, no clock, one-way dynamic (15 min).—Figure B.1.5.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with 15-min dynamic measurements). Table B.1.5.1 tabulates the weighted system availabilities from figure B.1.5.1. Table B.1.5.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

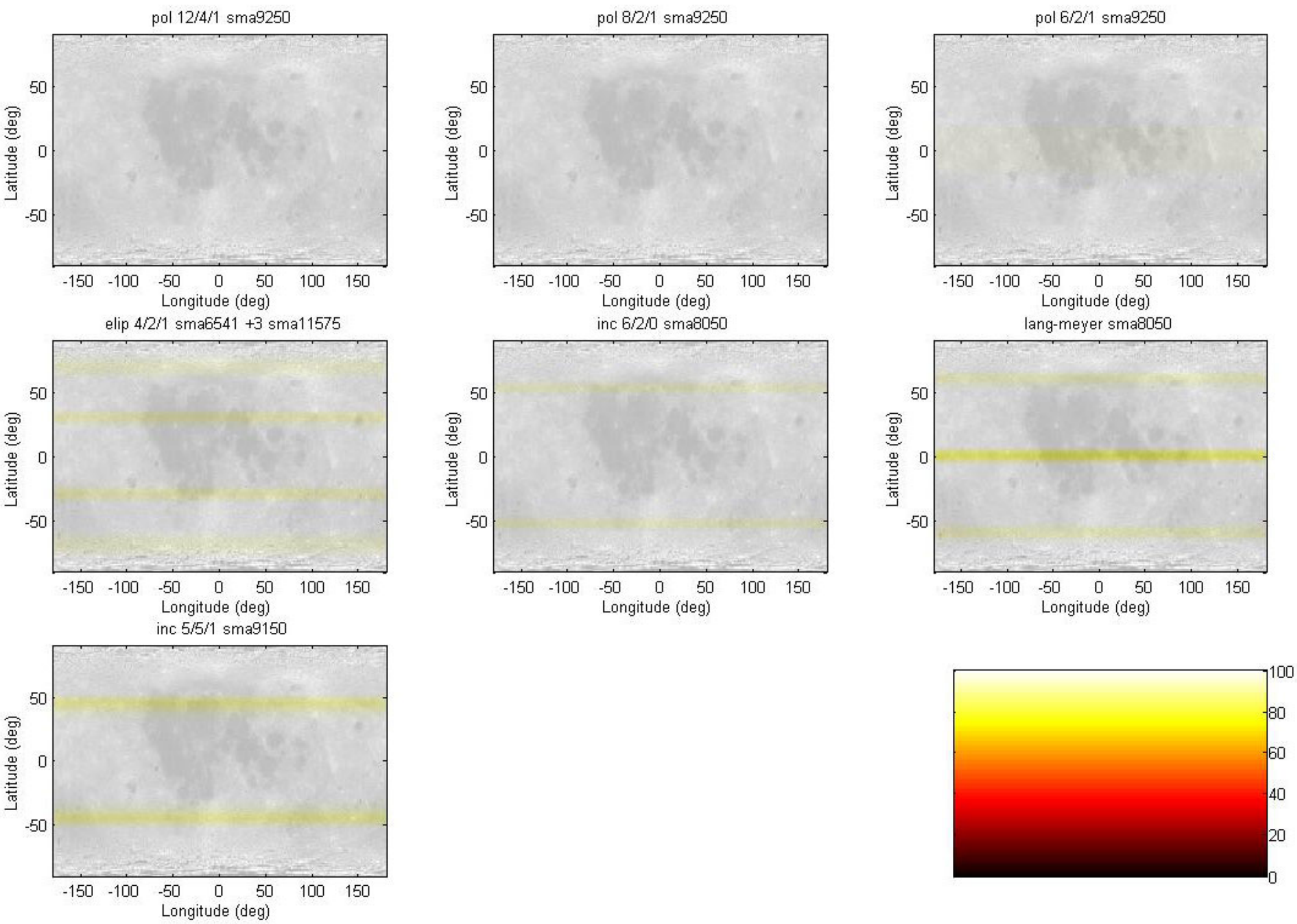

Figure B.1.5.1.—Lunar system availability results.

TABLE B.1.5.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.67	100.00	99.57	99.67	99.41
Pol 6/2/1 SMA 9250	99.28	100.00	99.04	99.28	99.71
Elip 4/2/1 SMA 6541 + 3 SMA 11575	98.03	100.00	98.09	98.03	97.42
Inc 6/2/0 SMA 8050	99.44	100.00	99.99	99.44	100.00
Lang-Meyer SMA 8050	97.70	100.00	97.84	97.69	97.18
Inc 5/5/1 SMA 9150	98.07	100.00	97.44	98.08	99.88

TABLE B.1.5.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.58	0.01	0.75	0.56	0.95
Pol 6/2/1 SMA 9250	1.89	1.84	2.31	1.86	3.97
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.87	1.06	0.55	0.87	0.70
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.87	0.00	0.54	0.87	0.68
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.35	0.00	2.78	2.36	2.92
Inc 6/2/0 SMA 8050	2.22	0.00	6.61	2.25	8.44
Lang-Meyer SMA 8050 - v1	3.52	0.00	4.46	3.48	5.62
Lang-Meyer SMA 8050 - v2	3.02	10.86	1.85	3.03	1.12
Inc 5/5/1 SMA 9150	5.71	3.29	5.06	5.73	4.24

B.1.6 Good terrain, no clock, one-way dynamic (1 hr).—Figure B.1.6.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with 1-hr dynamic measurements). Table B.1.6.1 tabulates the weighted system availabilities from figure B.1.6.1. Table B.1.6.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

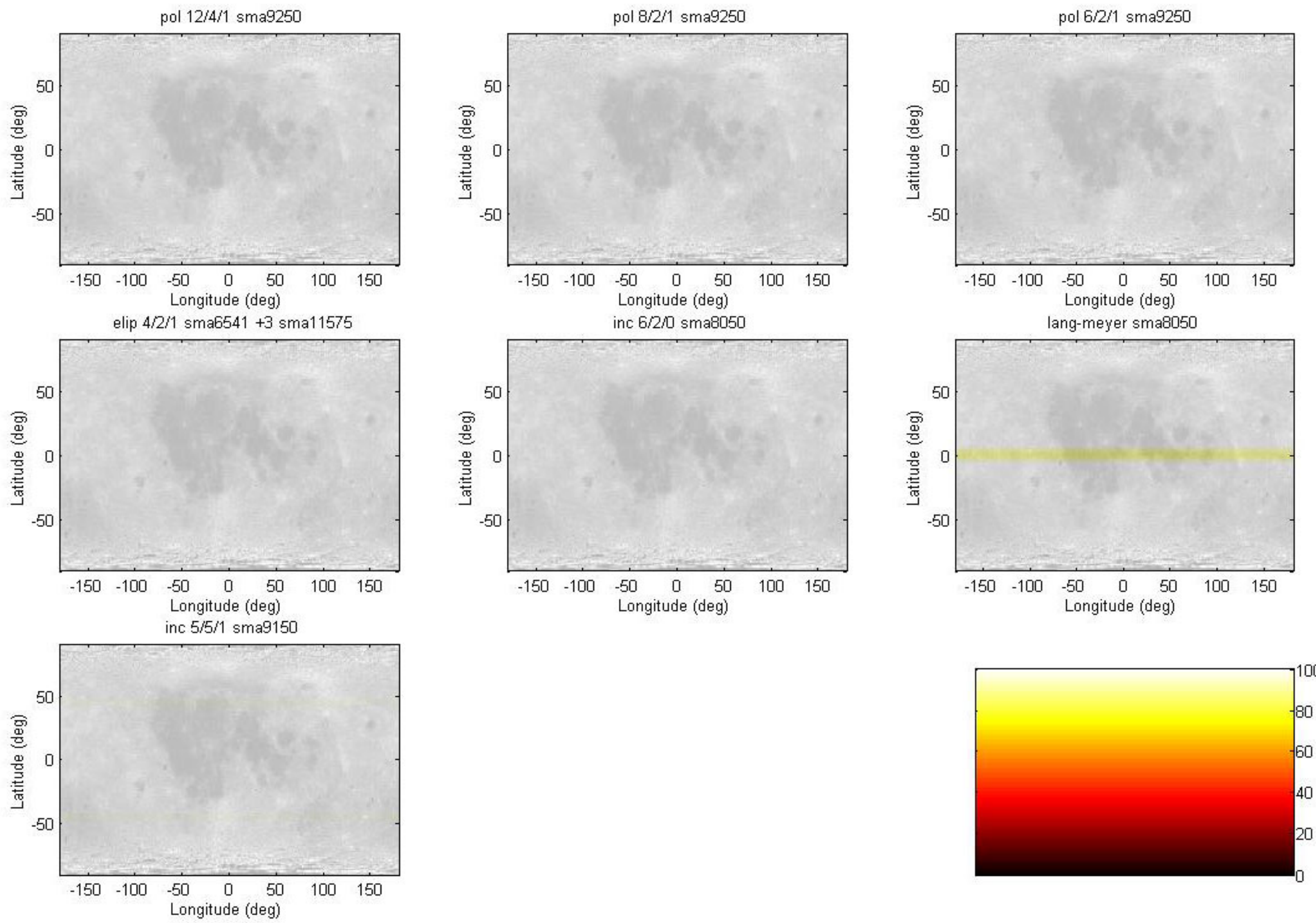

Figure B.1.6.1.—Lunar system availability results.

TABLE B.1.6.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.97	100.00	99.96	99.97	99.96
Pol 6/2/1 SMA 9250	99.91	100.00	99.88	99.91	99.83
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.98	100.00	99.99	99.98	99.99
Inc 6/2/0 SMA 8050	99.94	100.00	100.00	99.94	100.00
Lang-Meyer SMA 8050	98.82	100.00	98.53	98.83	98.02
Inc 5/5/1 SMA 9150	99.70	100.00	99.60	99.69	100.00

TABLE B.1.6.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.26	0.00	0.34	0.25	0.47
Pol 6/2/1 SMA 9250	1.24	0.15	1.63	1.23	2.16
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.22	0.17	0.08	0.22	0.08
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.22	0.00	0.07	0.22	0.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	1.48	0.00	1.94	1.49	2.17
Inc 6/2/0 SMA 8050	1.46	0.00	1.61	1.48	1.09
Lang-Meyer SMA 8050 - v1	1.69	0.00	2.23	1.68	3.00
Lang-Meyer SMA 8050 - v2	1.96	6.75	0.99	1.98	0.51
Inc 5/5/1 SMA 9150	4.31	1.28	3.86	4.31	2.65

B.1.7 No terrain, 3-hr clock synchronization, one-way kinematic.—Figure B.1.7.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with kinematic measurements). Table B.1.7.1 tabulates the weighted system availabilities from figure B.1.7.1. Table B.1.7.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

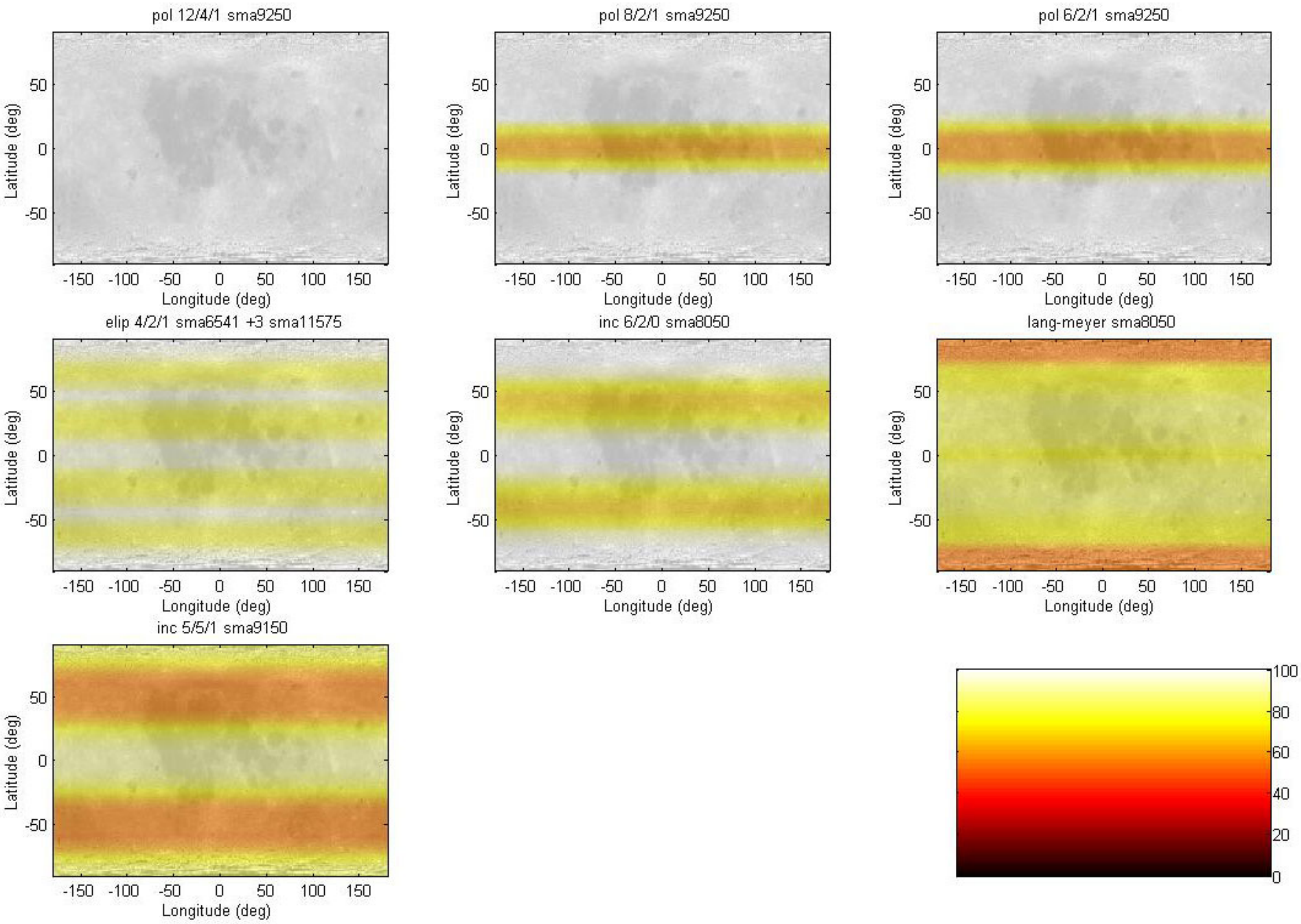

Figure B.1.7.1.—Lunar system availability results.

TABLE B.1.7.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	90.19	100.00	86.97	90.19	82.45
Pol 6/2/1 SMA 9250	87.26	99.92	83.10	87.27	77.14
Elip 4/2/1 SMA 6541 + 3 SMA 11575	86.78	97.61	87.12	86.79	85.62
Inc 6/2/0 SMA 8050	84.55	100.00	83.33	84.55	88.50
Lang-Meyer SMA 8050	78.47	54.30	81.28	78.44	81.07
Inc 5/5/1 SMA 9150	70.91	82.12	74.38	70.94	80.89

TABLE B.1.7.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.05	0.00	0.06	0.05	0.08
Pol 8/2/1 SMA 9250	6.99	8.64	6.74	6.98	6.78
Pol 6/2/1 SMA 9250	22.14	24.98	21.49	22.12	20.37
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	11.71	21.57	12.18	11.70	12.15
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	11.71	0.36	12.13	11.74	12.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	14.78	11.75	15.32	14.70	14.63
Inc 6/2/0 SMA 8050	22.56	25.59	19.18	22.67	23.20
Lang-Meyer SMA 8050 - v1	16.15	0.00	17.21	16.01	14.49
Lang-Meyer SMA 8050 - v2	15.91	26.81	15.68	15.95	14.96
Inc 5/5/1 SMA 9150	24.18	31.86	25.37	24.24	27.83

B.1.8 No terrain, 3-hr clock synchronization, one-way dynamic (15 min).—Figure B.1.8.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with 15-min dynamic measurements). Table B.1.8.1 tabulates the weighted system availabilities from figure B.1.8.1. Table B.1.8.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

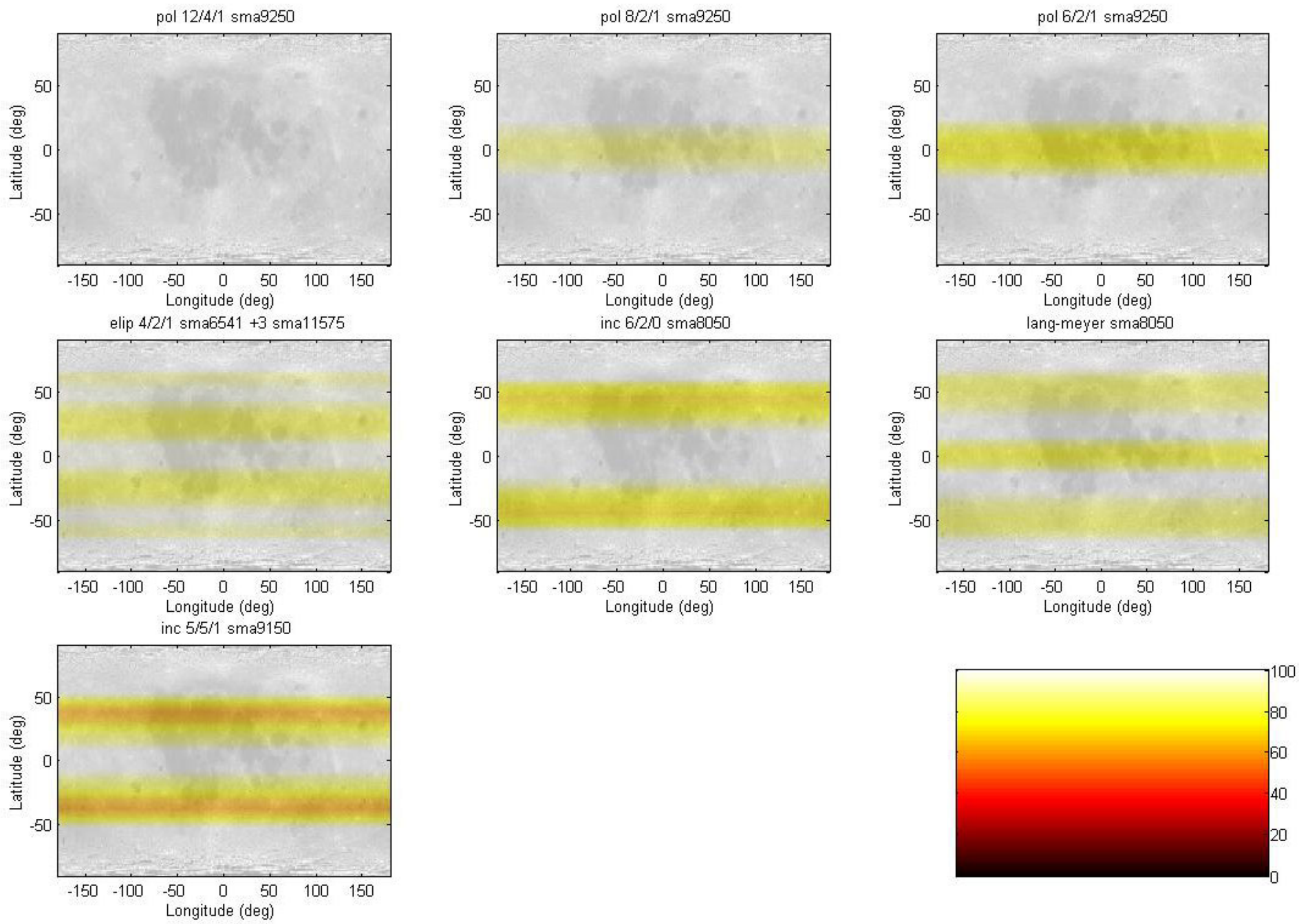

Figure B.1.8.1.—Lunar system availability results.

TABLE B.1.8.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	96.58	100.00	95.45	96.58	93.86
Pol 6/2/1 SMA 9250	92.23	100.00	89.68	92.22	86.04
Elip 4/2/1 SMA 6541 + 3 SMA 11575	90.65	100.00	89.03	90.64	87.53
Inc 6/2/0 SMA 8050	89.11	100.00	88.05	89.11	93.94
Lang-Meyer SMA 8050	90.73	99.88	90.89	90.73	92.53
Inc 5/5/1 SMA 9150	85.32	100.00	80.53	85.34	85.50

TABLE B.1.8.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	2.64	2.91	2.75	2.64	3.18
Pol 6/2/1 SMA 9250	7.25	15.89	5.85	7.29	5.44
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	6.73	1.17	7.76	6.70	9.34
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	6.72	0.00	7.71	6.71	9.13
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.43	0.00	2.85	2.42	2.14
Inc 6/2/0 SMA 8050	5.54	0.00	6.69	5.66	6.66
Lang-Meyer SMA 8050 - v1	8.34	0.00	9.91	8.27	7.92
Lang-Meyer SMA 8050 - v2	4.03	11.04	3.59	4.07	4.09
Inc 5/5/1 SMA 9150	10.28	3.44	10.54	10.38	12.25

B.1.9 No terrain, 3-hr clock synchronization, one-way dynamic (1 hr).—Figure B.1.9.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with 1-hr dynamic measurements). Table B.1.9.1 tabulates the weighted system availabilities from figure B.1.9.1. Table B.1.9.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

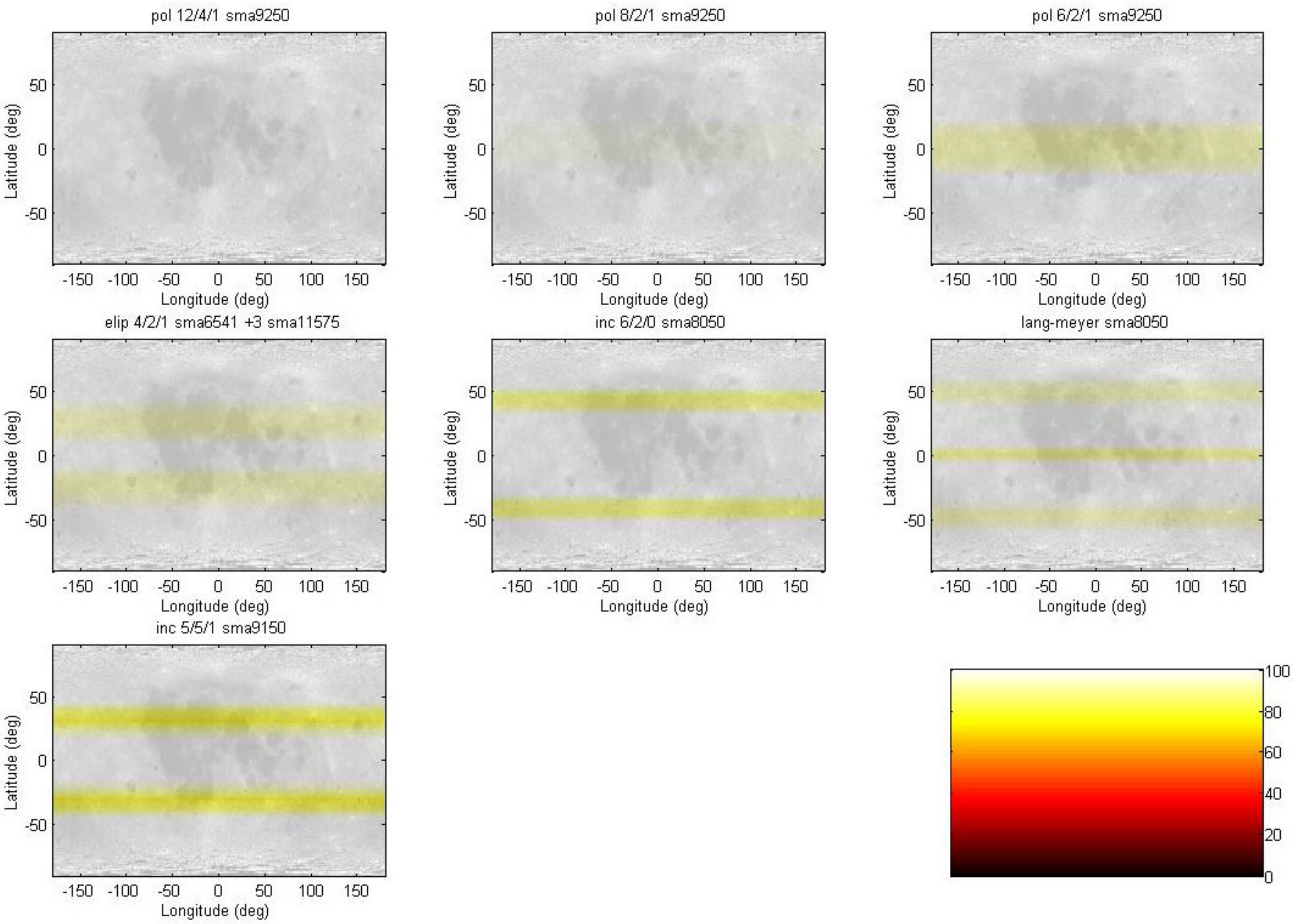

Figure B.1.9.1.—Lunar system availability results.

TABLE B.1.9.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.17	100.00	98.90	99.17	98.52
Pol 6/2/1 SMA 9250	97.01	100.00	96.03	97.01	94.64
Elip 4/2/1 SMA 6541 + 3 SMA 11575	96.52	100.00	95.45	96.51	94.76
Inc 6/2/0 SMA 8050	96.74	100.00	95.68	96.74	100.00
Lang-Meyer SMA 8050	97.14	99.97	97.12	97.15	98.02
Inc 5/5/1 SMA 9150	93.52	100.00	91.40	93.54	92.21

TABLE B.1.9.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.99	0.00	1.22	0.99	1.55
Pol 6/2/1 SMA 9250	3.24	1.45	3.17	3.27	3.47
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.26	0.19	2.21	2.25	2.91
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.24	0.00	2.20	2.20	2.83
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	1.91	0.00	2.53	1.90	2.75
Inc 6/2/0 SMA 8050	3.12	0.00	3.55	3.20	3.05
Lang-Meyer SMA 8050 - v1	5.34	0.00	6.56	5.27	5.77
Lang-Meyer SMA 8050 - v2	2.03	6.92	1.22	2.06	1.10
Inc 5/5/1 SMA 9150	6.35	1.35	6.32	6.42	6.04

B.1.10 Good terrain, 3-hr clock synchronization, one-way kinematic.—Figure B.1.10.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with kinematic measurements). Table B.1.10.1 tabulates the weighted system availabilities from figure B.1.10.1. Table B.1.10.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

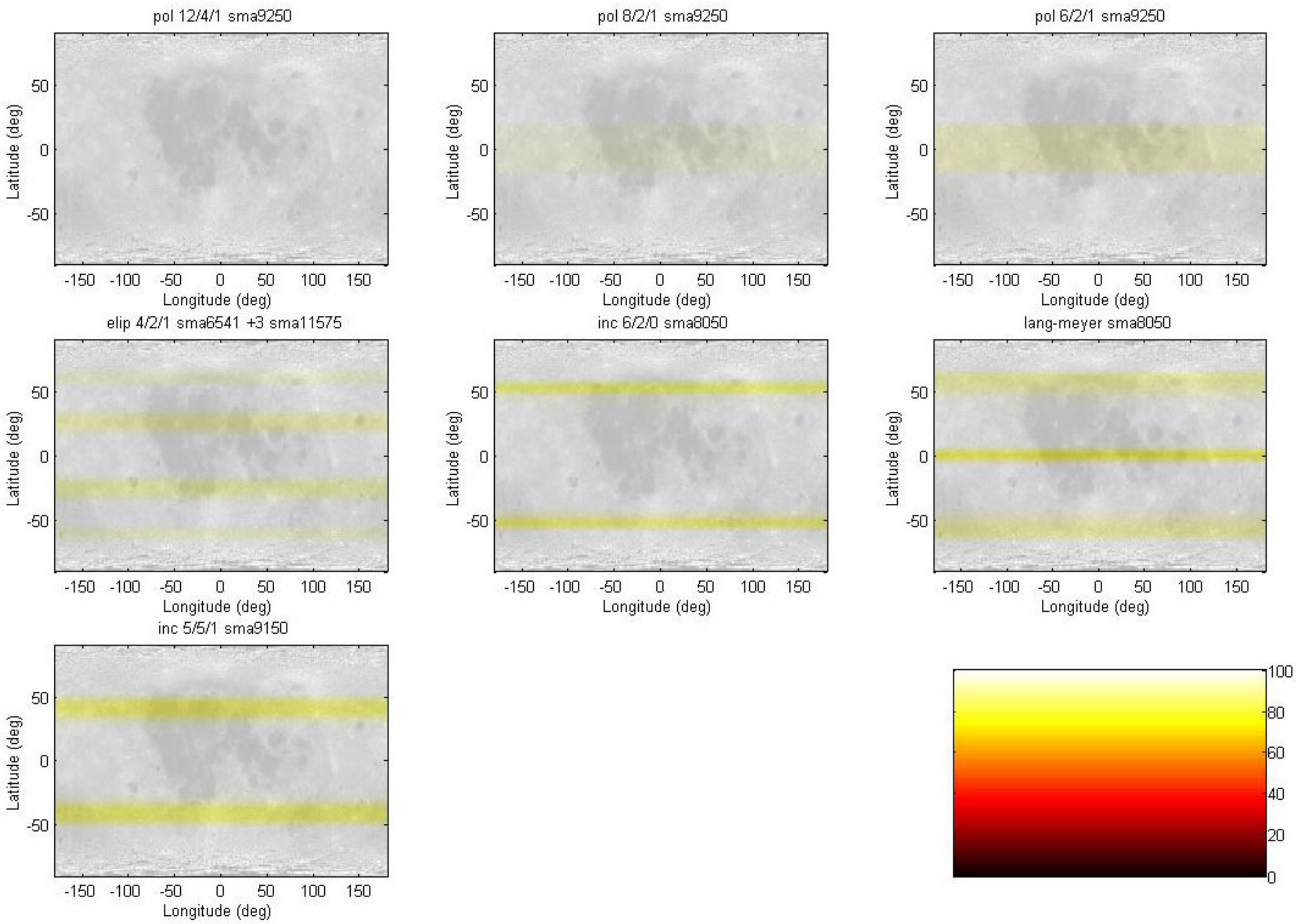

Figure B.1.10.1.—Lunar system availability results.

TABLE B.1.10.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	98.78	100.00	98.38	98.78	97.85
Pol 6/2/1 SMA 9250	97.63	100.00	96.86	97.63	95.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575	96.89	100.00	96.61	96.87	95.44
Inc 6/2/0 SMA 8050	97.91	100.00	99.41	97.91	100.00
Lang-Meyer SMA 8050	96.17	99.84	97.10	96.18	96.82
Inc 5/5/1 SMA 9150	95.73	100.00	94.33	95.78	99.02

TABLE B.1.10.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.97	0.07	1.12	0.99	1.37
Pol 6/2/1 SMA 9250	3.07	6.03	3.25	3.15	3.85
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.16	1.24	0.75	1.14	0.91
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.15	0.00	0.73	1.14	0.87
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.29	0.00	4.17	3.27	4.27
Inc 6/2/0 SMA 8050	3.62	0.00	4.29	3.73	3.20
Lang-Meyer SMA 8050 - v1	4.68	0.00	5.75	4.56	6.45
Lang-Meyer SMA 8050 - v2	3.27	11.32	2.34	3.31	1.69
Inc 5/5/1 SMA 9150	6.38	3.57	5.66	6.52	5.53

B.1.11 Good terrain, 3-hr clock synchronization, one-way dynamic (15 min).—Figure B.1.11.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with 15-min dynamic measurements). Table B.1.11.1 tabulates the weighted system availabilities from figure B.1.11.1. Table B.1.11.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

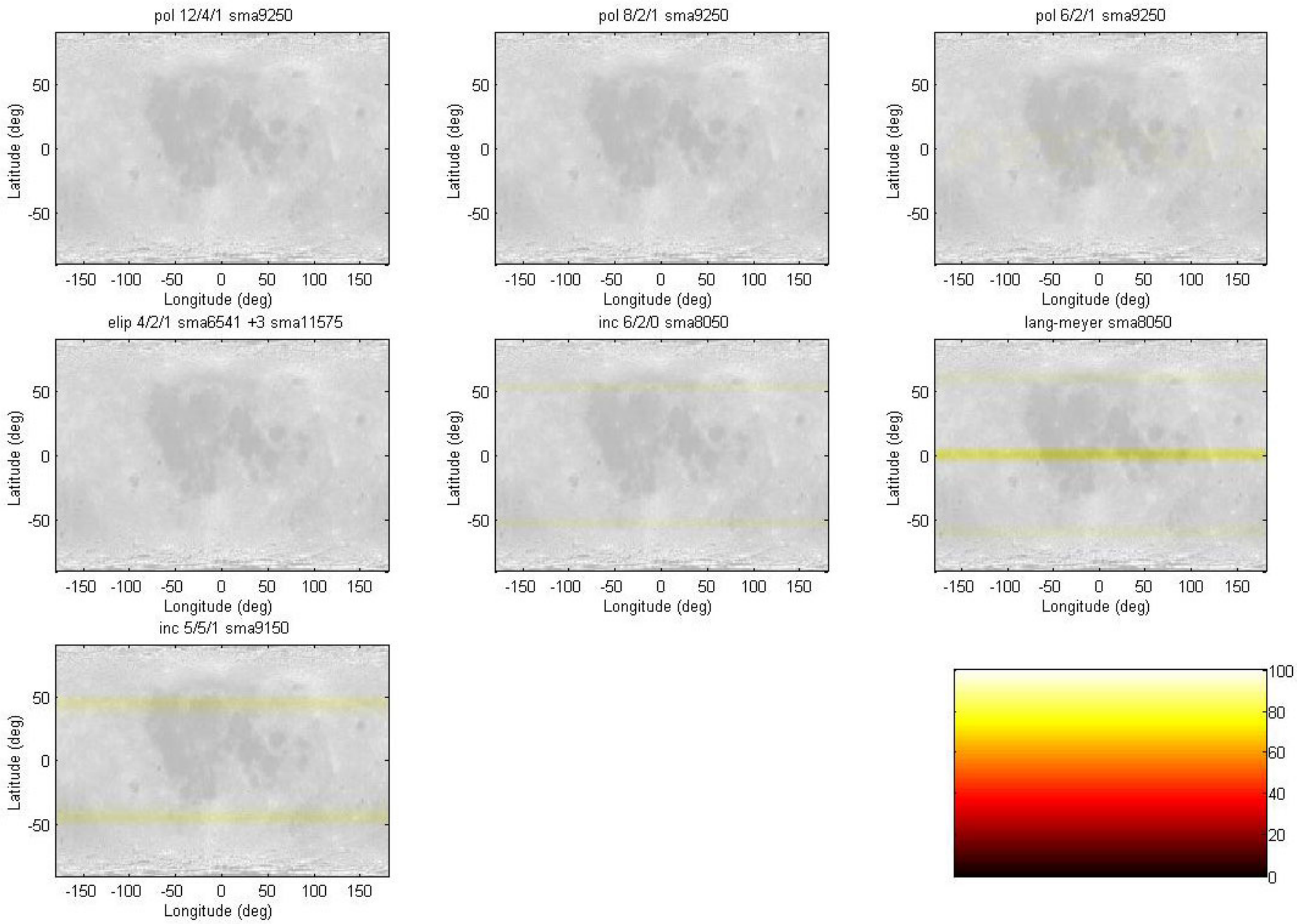

Figure B.1.11.1.—Lunar system availability results.

TABLE B.1.11.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.73	100.00	99.64	99.73	99.51
Pol 6/2/1 SMA 9250	99.47	100.00	99.30	99.47	99.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.74	100.00	99.75	99.73	99.65
Inc 6/2/0 SMA 8050	99.59	100.00	99.99	99.59	100.00
Lang-Meyer SMA 8050	97.97	100.00	97.86	97.97	97.18
Inc 5/5/1 SMA 9150	98.68	100.00	98.25	98.68	99.89

TABLE B.1.11.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.45	0.00	0.60	0.44	0.78
Pol 6/2/1 SMA 9250	1.59	0.43	2.05	1.58	2.72
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.58	0.81	0.34	0.58	0.41
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.58	0.00	0.33	0.57	0.42
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.08	0.00	2.71	2.09	3.04
Inc 6/2/0 SMA 8050	2.03	0.00	2.26	12.05	1.63
Lang-Meyer SMA 8050 - v1	3.00	0.00	3.84	2.97	4.97
Lang-Meyer SMA 8050 - v2	2.81	9.94	1.66	2.82	0.98
Inc 5/5/1 SMA 9150	5.39	2.79	4.80	5.40	3.82

B.1.12 Good terrain, 3-hr clock synchronization, one-way dynamic (1 hr).—Figure B.1.12.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with 1-hr dynamic measurements). Table B.1.12.1 tabulates the weighted system availabilities from figure B.1.12.1. Table B.1.12.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

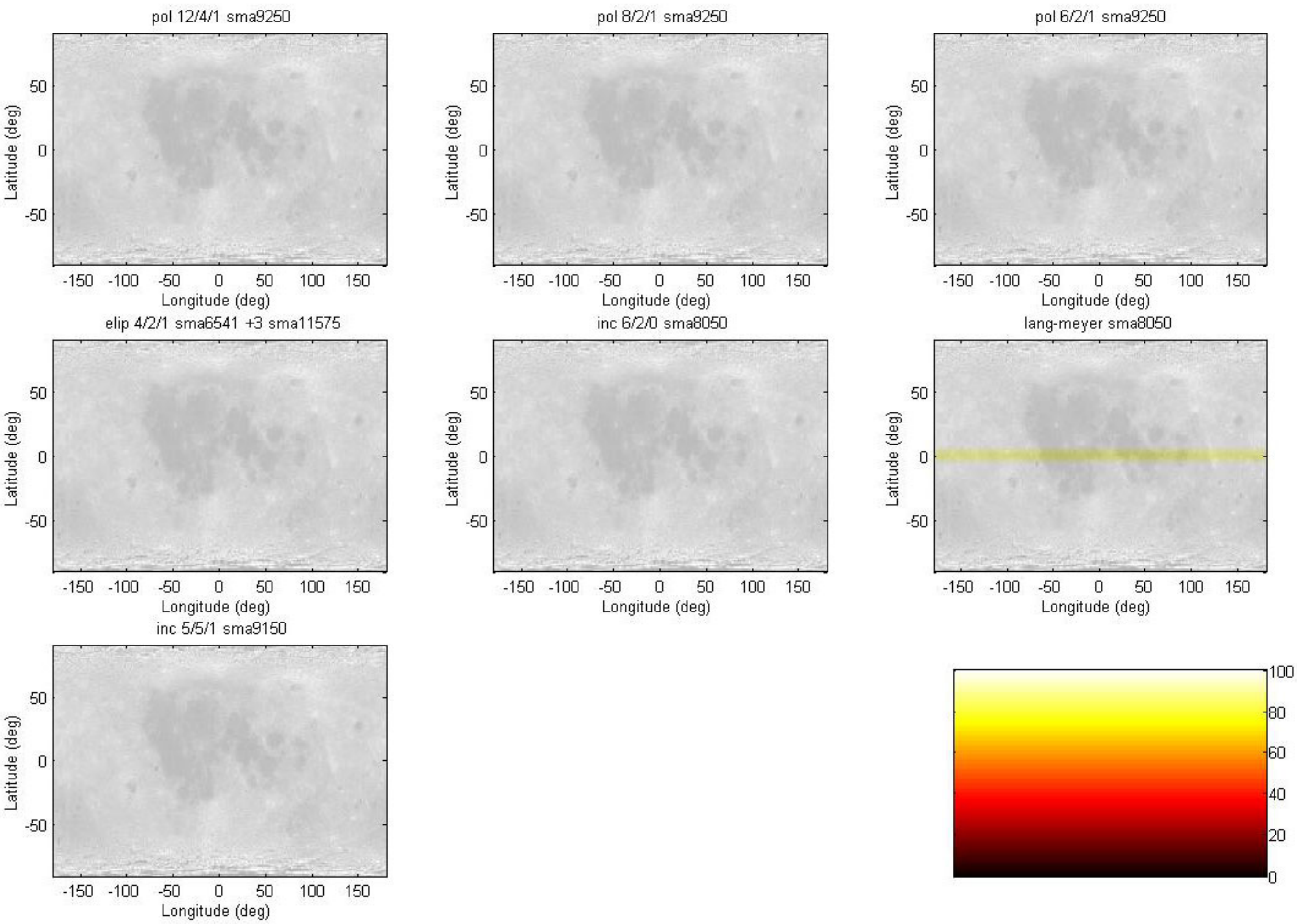

Figure B.1.12.1.—Lunar system availability results.

TABLE B.1.12.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.98	100.00	99.97	99.98	99.96
Pol 6/2/1 SMA 9250	99.96	100.00	99.94	99.96	99.93
Elip 4/2/1 SMA 6541 + 3 SMA 11575	100.00	100.00	100.00	100.00	100.00
Inc 6/2/0 SMA 8050	100.00	100.00	100.00	100.00	100.00
Lang-Meyer SMA 8050	98.89	100.00	98.53	98.89	98.02
Inc 5/5/1 SMA 9150	99.99	100.00	99.99	99.99	100.00

TABLE B.1.12.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.20	0.00	0.27	0.20	0.37
Pol 6/2/1 SMA 9250	1.13	0.00	1.49	1.12	2.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.07	0.08	0.04	0.07	0.02
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.07	0.00	0.03	0.07	0.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	1.38	0.00	1.82	1.39	2.05
Inc 6/2/0 SMA 8050	1.34	0.00	1.48	1.36	1.00
Lang-Meyer SMA 8050 - v1	1.38	0.00	1.86	1.37	2.51
Lang-Meyer SMA 8050 - v2	1.76	5.83	0.84	1.77	0.43
Inc 5/5/1 SMA 9150	4.03	0.94	3.63	4.04	2.40

B.1.13 No terrain, two-way kinematic.—Figure B.1.13.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with kinematic measurements). Table B.1.13.1 tabulates the weighted system availabilities from figure B.1.13.1. Table B.1.13.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

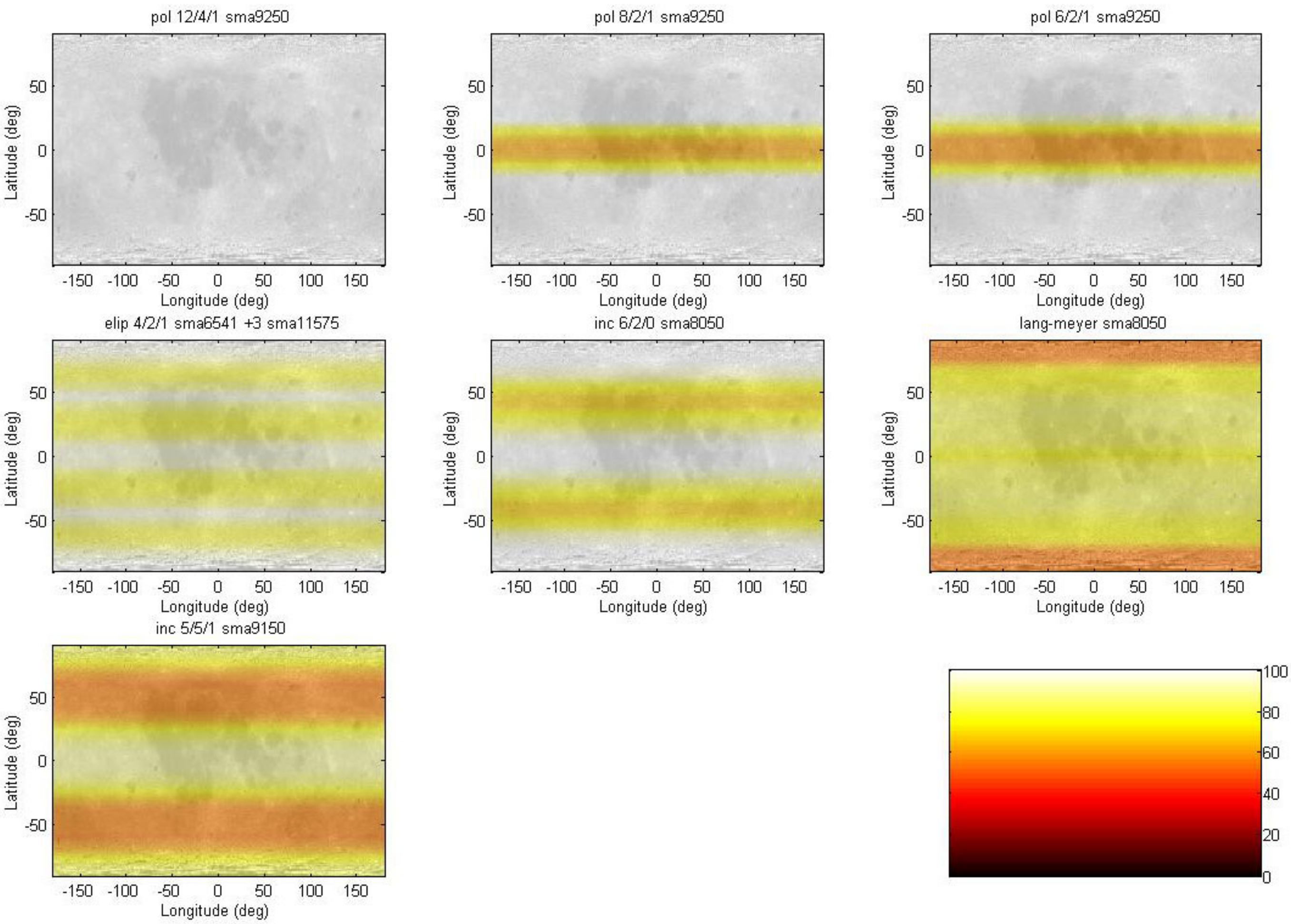

Figure B.1.13.1.—Lunar system availability results.

TABLE B.1.13.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	90.19	100.00	86.98	90.20	82.45
Pol 6/2/1 SMA 9250	87.30	100.00	83.14	87.30	77.18
Elip 4/2/1 SMA 6541 + 3 SMA 11575	86.82	97.61	87.14	86.82	85.65
Inc 6/2/0 SMA 8050	85.04	100.00	83.98	85.04	89.37
Lang-Meyer SMA 8050	78.48	54.30	81.28	78.47	81.09
Inc 5/5/1 SMA 9150	70.91	82.12	74.38	70.94	80.89

TABLE B.1.13.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.05	0.00	0.06	0.05	0.08
Pol 8/2/1 SMA 9250	6.97	8.64	6.74	6.95	6.78
Pol 6/2/1 SMA 9250	22.09	24.99	21.45	22.05	20.34
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	11.73	21.57	12.19	11.71	12.17
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	11.72	0.36	12.13	11.75	12.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	14.76	11.75	15.31	14.68	14.62
Inc 6/2/0 SMA 8050	22.70	25.59	22.37	22.79	23.46
Lang-Meyer SMA 8050 - v1	16.02	0.00	17.01	15.90	14.21
Lang-Meyer SMA 8050 - v2	15.92	26.81	15.68	15.97	14.96
Inc 5/5/1 SMA 9150	24.18	31.86	25.37	24.23	27.83

***B.1.14 No terrain, two-way dynamic (15 min)*.**—Figure B.1.14.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with 15-min dynamic measurements). Table B.1.14.1 tabulates the weighted system availabilities from figure B.1.14.1. Table B.1.14.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

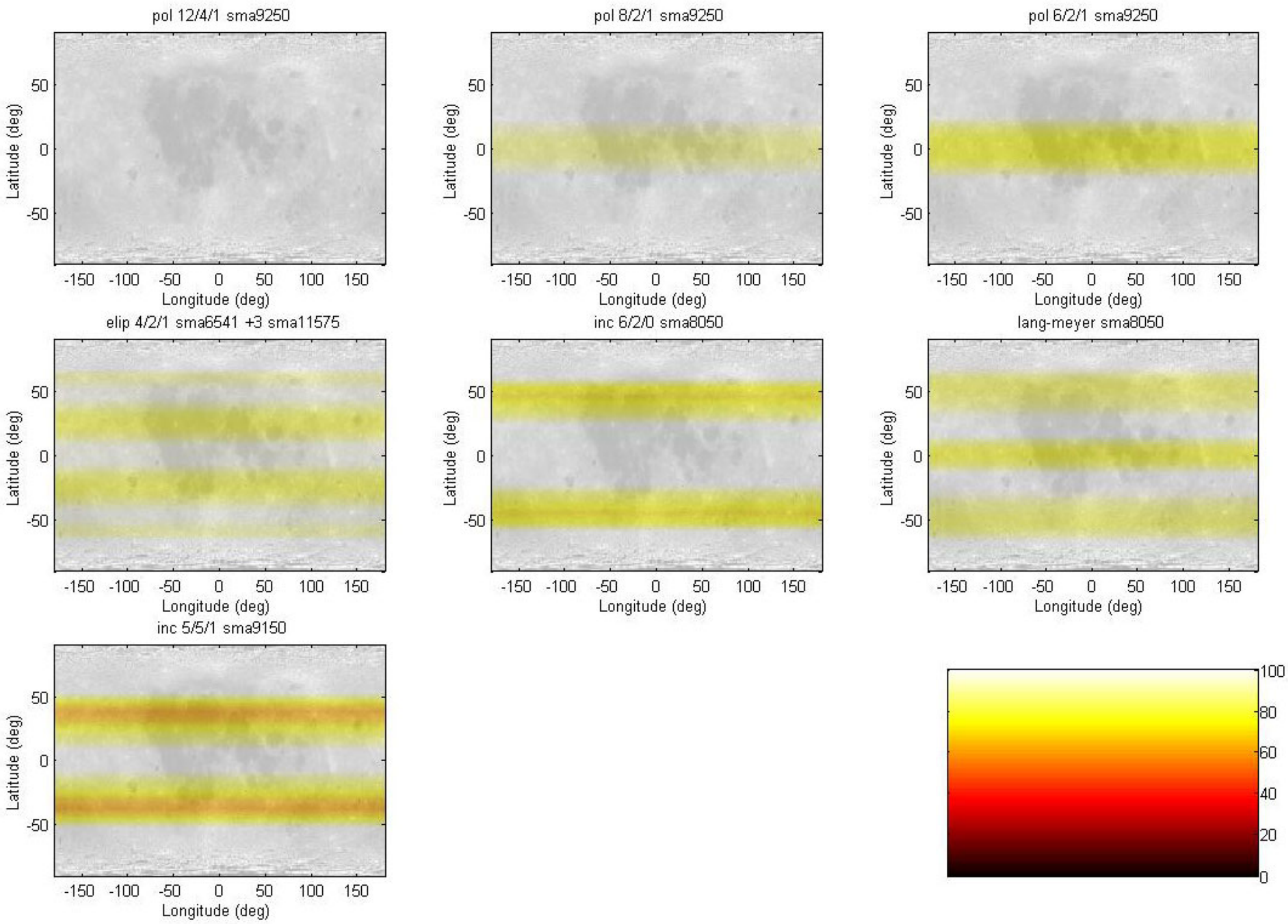

Figure B.1.14.1.—Lunar system availability results.

TABLE B.1.14.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	96.77	100.00	95.71	96.77	94.19
Pol 6/2/1 SMA 9250	92.82	100.00	90.47	92.82	87.10
Elip 4/2/1 SMA 6541 + 3 SMA 11575	90.85	100.00	89.31	90.85	87.53
Inc 6/2/0 SMA 8050	91.33	100.00	90.98	91.33	96.99
Lang-Meyer SMA 8050	90.75	100.00	90.90	90.74	92.56
Inc 5/5/1 SMA 9150	85.35	100.00	80.54	85.36	85.50

TABLE B.1.14.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	2.38	2.91	2.42	2.37	2.75
Pol 6/2/1 SMA 9250	6.92	15.89	5.53	6.88	5.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	6.71	1.17	7.75	6.68	9.34
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	6.69	0.00	7.70	6.69	9.13
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.52	0.00	2.98	2.52	2.08
Inc 6/2/0 SMA 8050	5.73	0.00	7.03	5.76	6.83
Lang-Meyer SMA 8050 - v1	8.28	0.00	9.81	8.22	7.77
Lang-Meyer SMA 8050 - v2	3.99	11.03	3.59	4.01	4.09
Inc 5/5/1 SMA 9150	10.16	3.44	10.53	10.18	12.24

B.1.15 No terrain, two-way dynamic (1 hr).—Figure B.1.15.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with 1-hr dynamic measurements). Table B.1.15.1 tabulates the weighted system availabilities from figure B.1.15.1. Table B.1.15.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

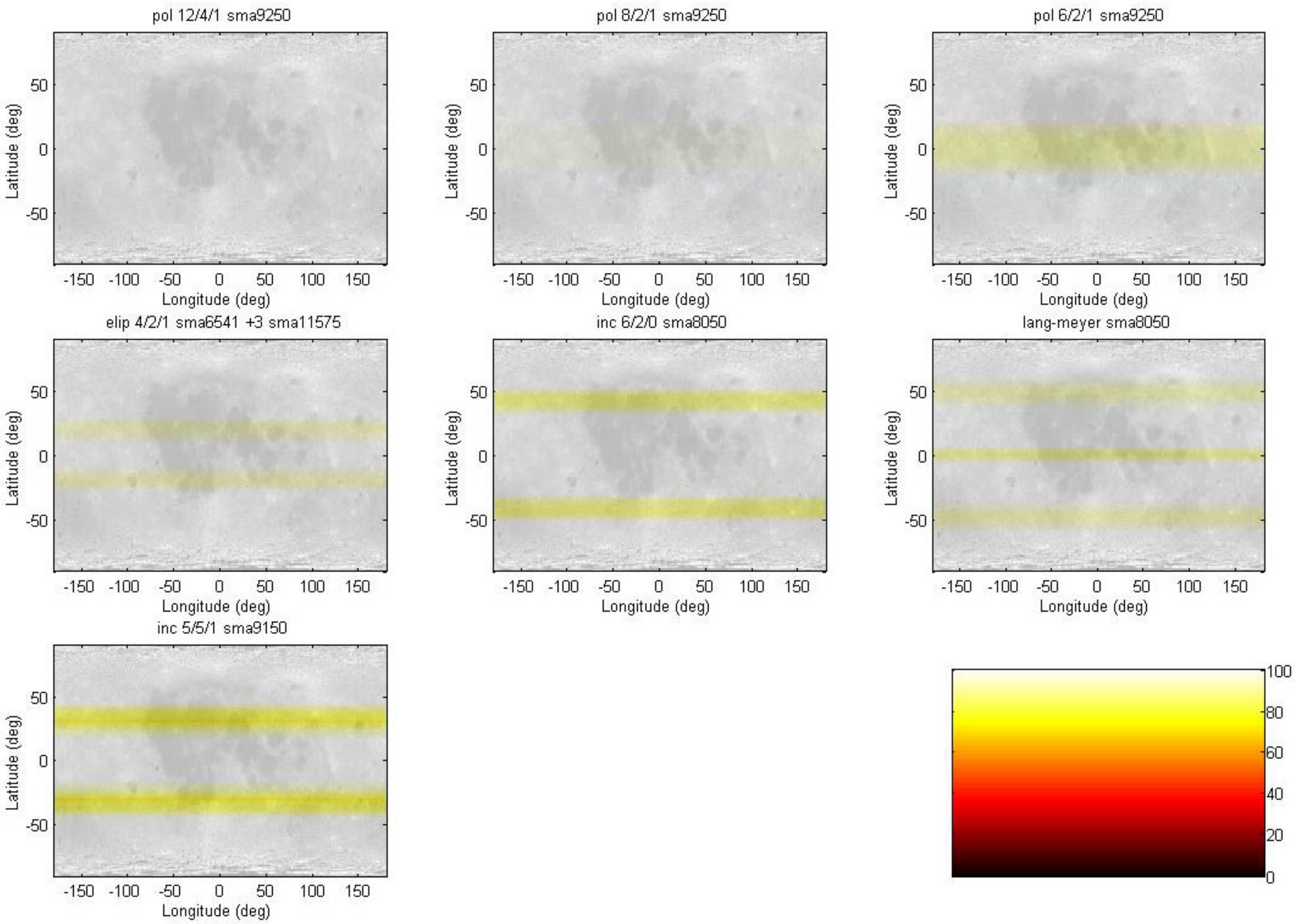

Figure B.1.15.1.—Lunar system availability results.

TABLE B.1.15.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.17	100.00	98.90	99.17	98.52
Pol 6/2/1 SMA 9250	97.02	100.00	96.04	97.02	94.64
Elip 4/2/1 SMA 6541 + 3 SMA 11575	98.03	100.00	97.45	98.03	96.56
Inc 6/2/0 SMA 8050	96.76	100.00	95.70	96.76	100.00
Lang-Meyer SMA 8050	97.15	100.00	97.13	97.15	98.02
Inc 5/5/1 SMA 9150	93.55	100.00	91.44	93.55	92.22

TABLE B.1.15.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.98	0.00	1.22	0.96	1.55
Pol 6/2/1 SMA 9250	2.89	1.45	2.76	2.87	2.92
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.17	0.19	2.10	2.15	2.84
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.14	0.00	2.06	2.12	2.75
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.06	0.00	2.73	2.07	3.05
Inc 6/2/0 SMA 8050	2.93	0.00	3.40	2.95	2.86
Lang-Meyer SMA 8050 - v1	5.28	0.00	6.44	5.23	5.65
Lang-Meyer SMA 8050 - v2	1.99	6.92	1.23	2.01	1.20
Inc 5/5/1 SMA 9150	6.23	1.35	6.30	6.23	6.04

***B.1.16 Good terrain, two-way kinematic*.**—Figure B.1.16.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with kinematic measurements). Table B.1.16.1 tabulates the weighted system availabilities from figure B.1.16.1. Table B.1.16.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

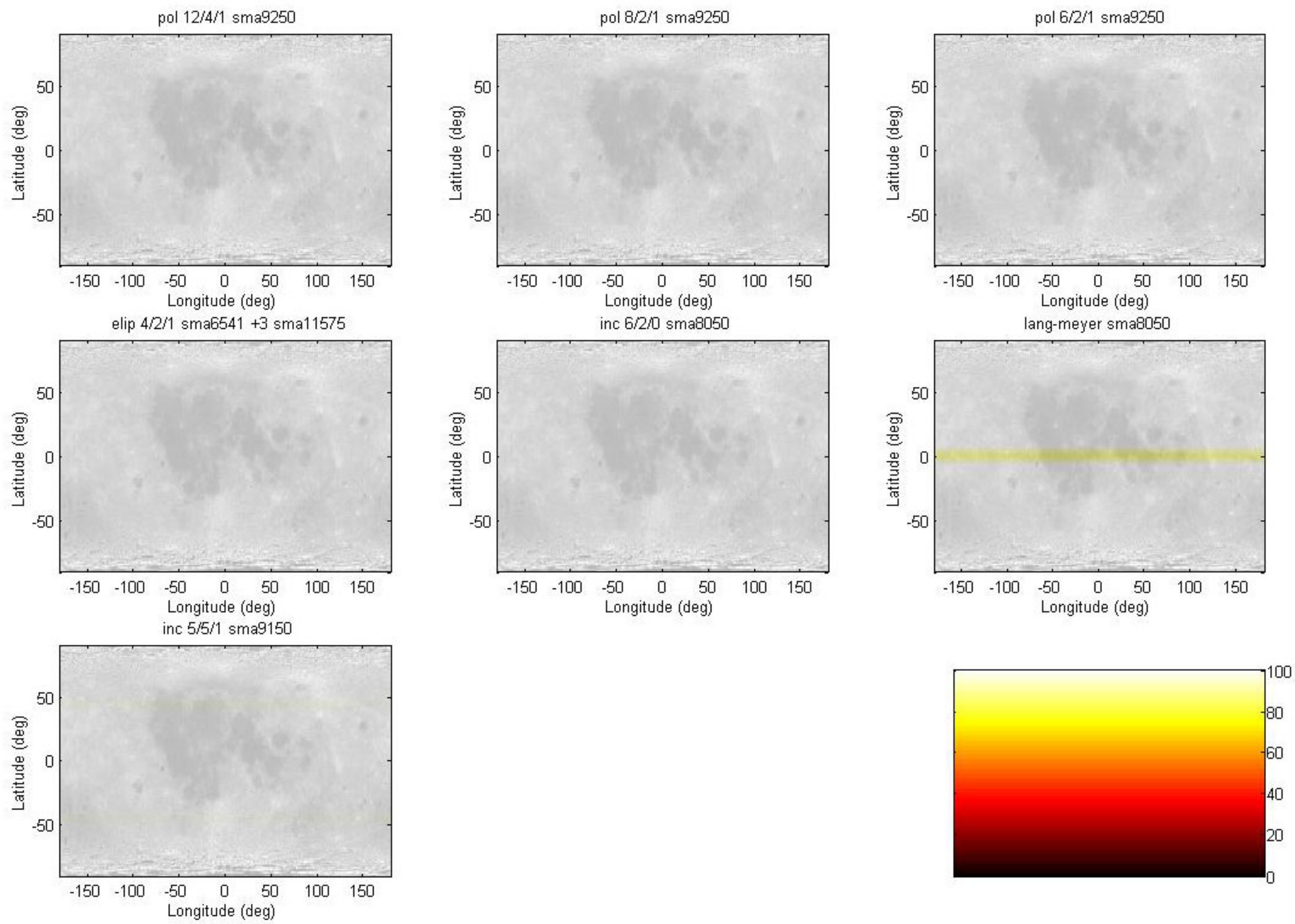

Figure B.1.16.1.—Lunar system availability results.

TABLE B.1.16.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	98.78	100.00	98.38	98.79	97.87
Pol 6/2/1 SMA 9250	97.65	100.00	96.89	97.65	95.80
Elip 4/2/1 SMA 6541 + 3 SMA 11575	96.91	100.00	96.63	96.91	95.46
Inc 6/2/0 SMA 8050	97.94	100.00	99.46	97.95	100.00
Lang-Meyer SMA 8050	96.20	100.00	97.12	96.20	96.86
Inc 5/5/1 SMA 9150	95.81	100.00	94.43	95.81	99.13

TABLE B.1.16.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.95	0.07	1.12	0.95	1.36
Pol 6/2/1 SMA 9250	2.55	6.03	2.66	2.55	3.13
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.14	1.24	0.73	1.13	0.91
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.13	0.00	0.71	1.13	0.87
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.25	0.00	2.77	2.26	2.79
Inc 6/2/0 SMA 8050	3.11	0.00	3.73	3.15	2.87
Lang-Meyer SMA 8050 - v1	4.54	0.00	5.50	4.50	6.30
Lang-Meyer SMA 8050 - v2	3.22	11.31	2.34	3.24	1.70
Inc 5/5/1 SMA 9150	6.22	3.57	5.64	6.22	5.53

***B.1.17 Good terrain, two-way dynamic (15 min)*.**—Figure B.1.17.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with 15-min dynamic measurements). Table B.1.17.1 tabulates the weighted system availabilities from figure B.1.17.1. Table B.1.17.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

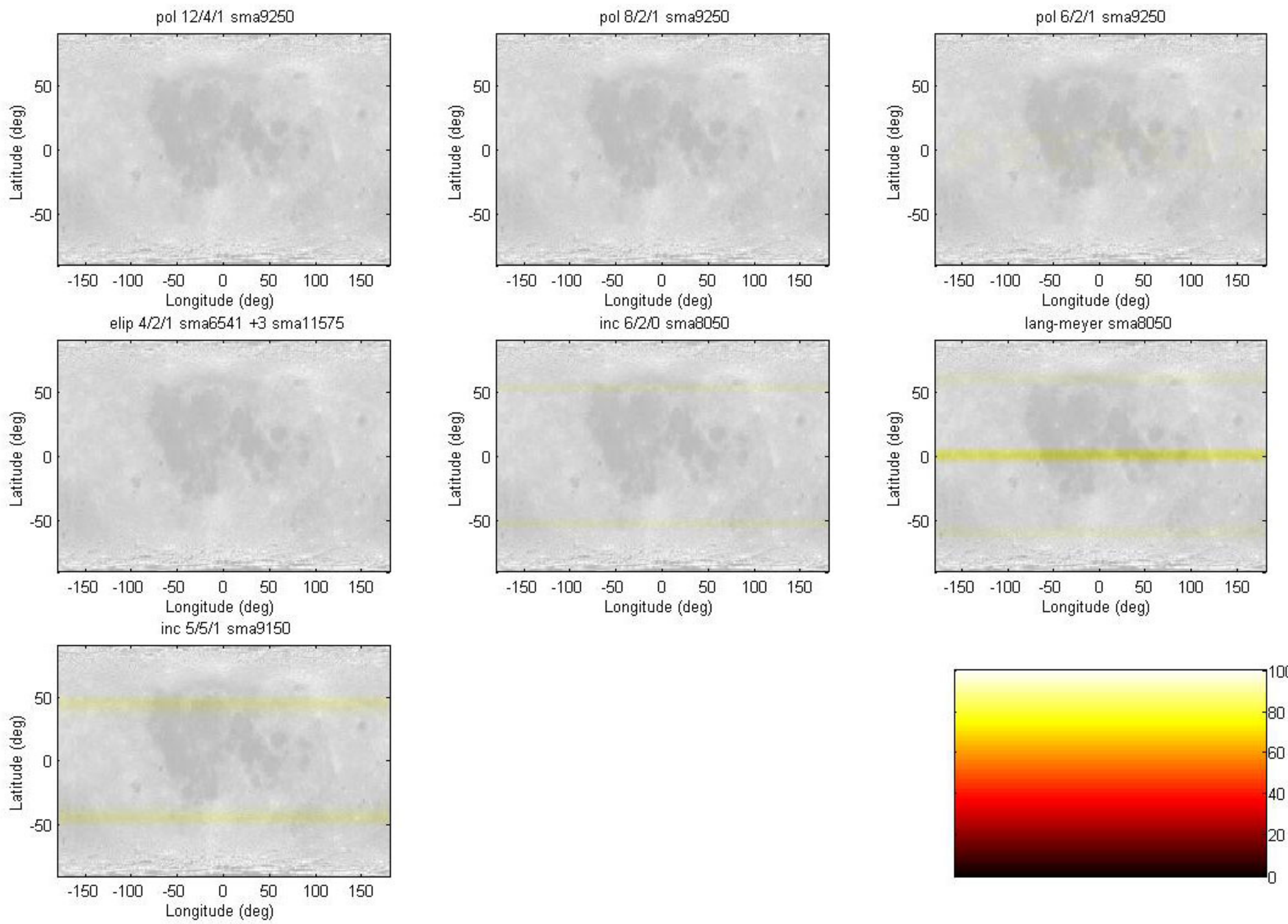

Figure B.1.17.1.—Lunar system availability results.

TABLE B.1.17.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.73	100.00	99.64	99.73	99.51
Pol 6/2/1 SMA 9250	99.47	100.00	99.30	99.47	99.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.75	100.00	99.75	99.75	99.66
Inc 6/2/0 SMA 8050	99.59	100.00	99.99	99.59	100.00
Lang-Meyer SMA 8050	97.97	100.00	97.86	97.97	97.18
Inc 5/5/1 SMA 9150	98.68	100.00	98.25	96.68	99.89

TABLE B.1.17.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.45	0.00	0.60	0.44	0.78
Pol 6/2/1 SMA 9250	1.59	0.43	2.05	1.58	2.72
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.58	0.81	0.33	0.58	0.41
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.57	0.00	0.32	0.57	0.42
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.08	0.00	2.70	2.10	3.03
Inc 6/2/0 SMA 8050	2.03	0.00	2.26	2.05	1.63
Lang-Meyer SMA 8050 - v1	3.00	0.00	3.84	2.97	4.97
Lang-Meyer SMA 8050 - v2	2.81	9.94	1.66	2.82	0.98
Inc 5/5/1 SMA 9150	5.39	2.79	4.80	3.40	3.82

B.1.18 Good terrain, two-way dynamic (1 hr).—Figure B.1.18.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with 1-hr dynamic measurements). Table B.1.18.1 tabulates the weighted system availabilities from figure B.1.18.1. Table B.1.18.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

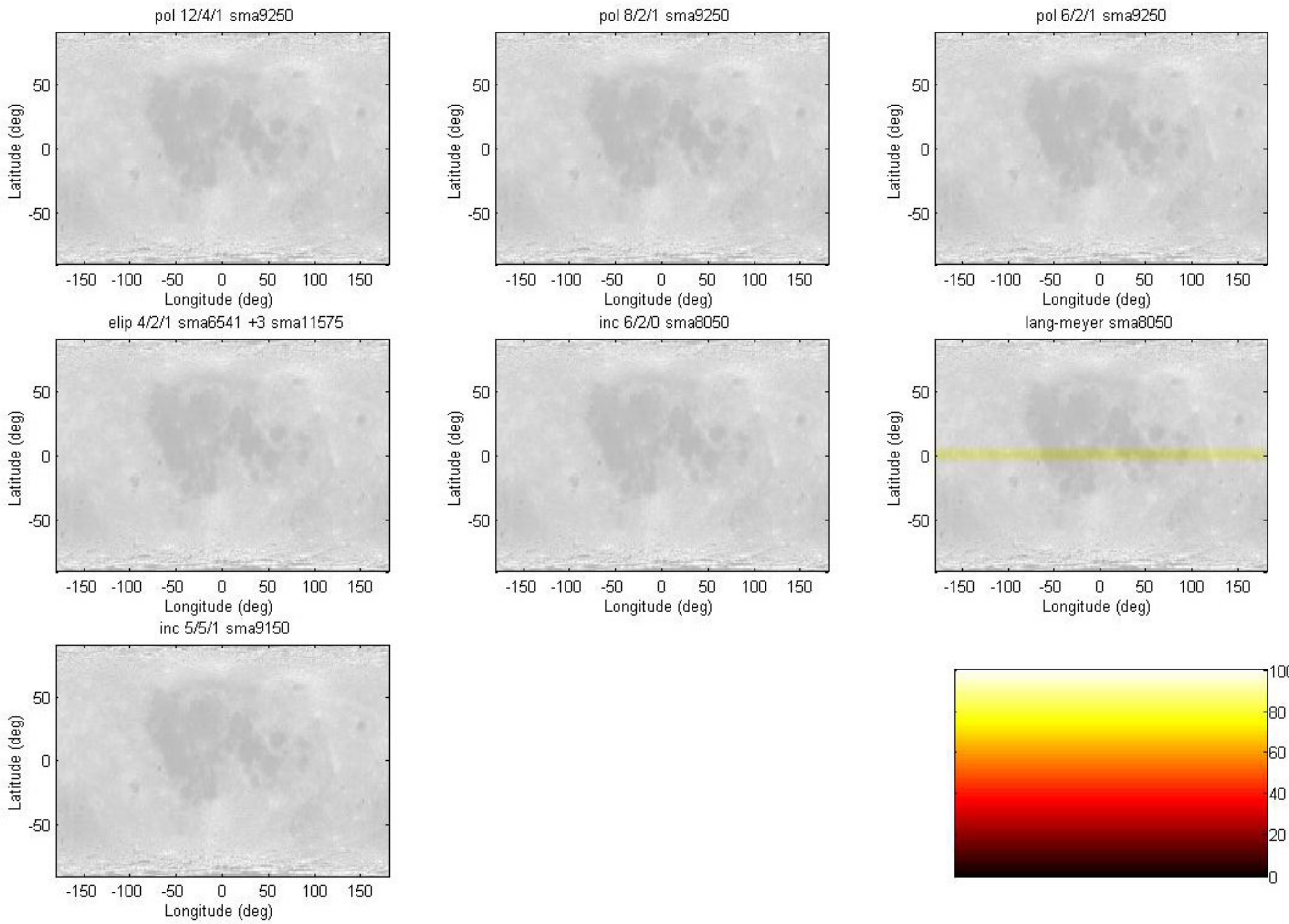

Figure B.1.18.1.—Lunar system availability results.

TABLE B.1.18.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.98	100.00	99.97	99.98	99.96
Pol 6/2/1 SMA 9250	99.96	100.00	99.94	99.96	99.93
Elip 4/2/1 SMA 6541 + 3 SMA 11575	100.00	100.00	100.00	100.00	100.00
Inc 6/2/0 SMA 8050	100.00	100.00	100.00	100.00	100.00
Lang-Meyer SMA 8050	98.89	100.00	98.53	98.89	98.02
Inc 5/5/1 SMA 9150	99.99	100.00	99.99	99.99	100.00

TABLE B.1.18.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.20	0.00	0.27	0.20	0.37
Pol 6/2/1 SMA 9250	1.12	0.00	1.49	1.12	2.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.07	0.08	0.04	0.07	0.02
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.07	0.00	0.03	0.07	0.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	1.38	0.00	1.82	1.39	2.05
Inc 6/2/0 SMA 8050	1.34	0.00	1.48	1.36	1.00
Lang-Meyer SMA 8050 - v1	1.38	0.00	1.86	1.37	2.51
Lang-Meyer SMA 8050 - v2	1.76	5.83	0.84	1.77	0.43
Inc 5/5/1 SMA 9150	4.03	0.94	3.63	4.04	2.40

B.2 User Minimum Elevation Angle of 10°

B.2.1 No terrain, no clock, one-way kinematic.—Figure B.2.1.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with kinematic measurements). Table B.2.1.1 tabulates the weighted system availabilities from figure B.2.1.1. Table B.2.1.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

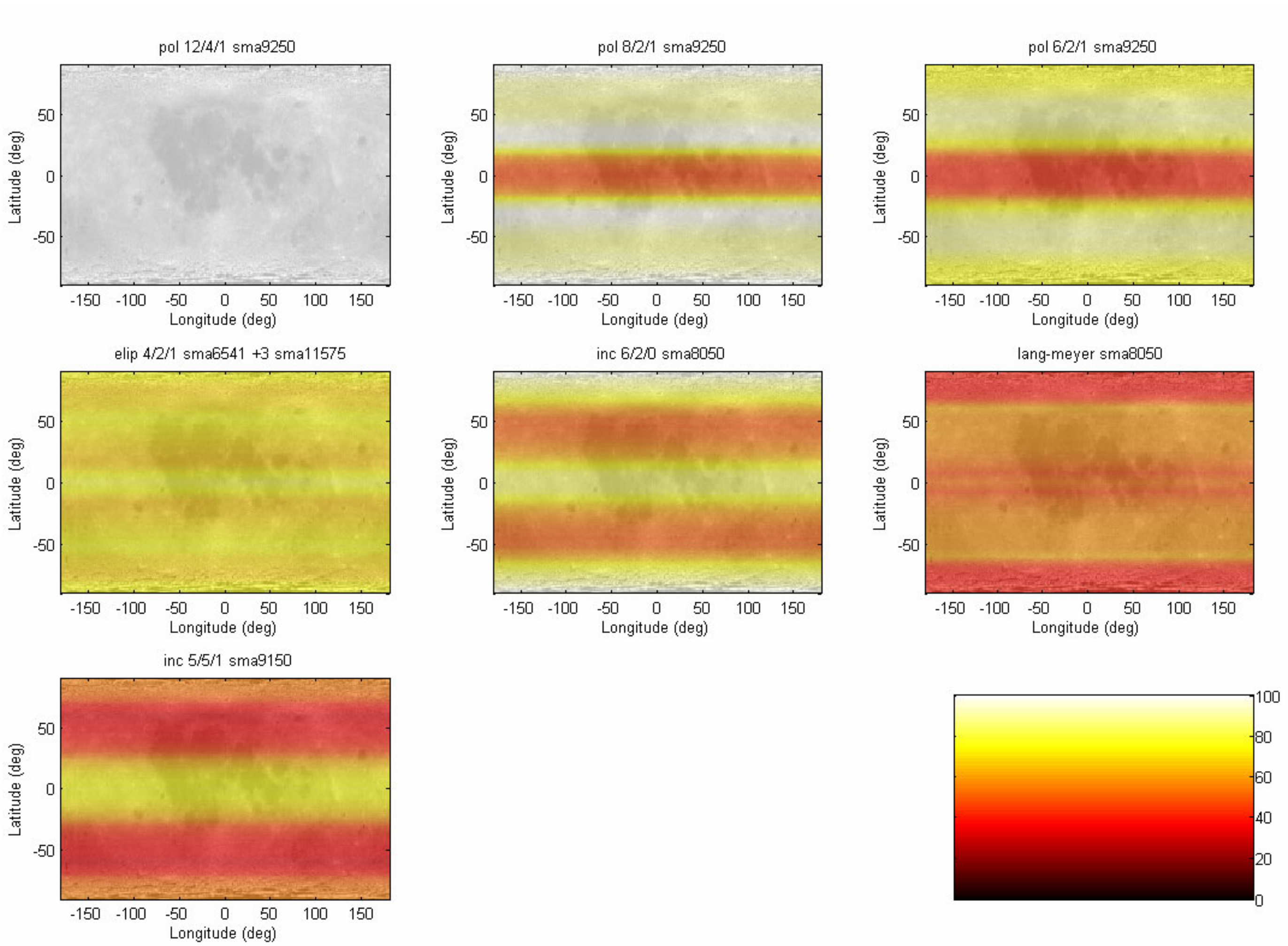

Figure B.2.1.1.—Lunar system availability results.

TABLE B.2.1.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.81	100.00	99.75	99.81	99.66
Pol 8/2/1 SMA 9250	79.04	95.96	75.61	79.04	69.07
Pol 6/2/1 SMA 9250	69.38	75.86	64.48	69.37	56.26
Elip 4/2/1 SMA 6541 + 3 SMA 11575	71.08	73.00	70.86	71.04	70.53
Inc 6/2/0 SMA 8050	65.41	90.88	65.17	65.42	70.29
Lang-Meyer SMA 8050	53.72	39.14	54.32	53.72	53.00
Inc 5/5/1 SMA 9150	53.51	54.20	58.15	53.53	65.01

TABLE B.2.1.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.95	0.00	1.26	0.95	1.68
Pol 8/2/1 SMA 9250	13.08	13.71	13.26	13.06	12.60
Pol 6/2/1 SMA 9250	21.38	19.77	20.20	21.33	17.80
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	13.69	20.53	13.77	13.69	13.70
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	13.70	1.21	13.73	13.74	13.66
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	18.86	21.64	18.39	18.76	17.99
Inc 6/2/0 SMA 8050	20.51	29.78	20.31	20.60	21.89
Lang-Meyer SMA 8050 - v1	21.24	0.00	24.59	21.08	24.32
Lang-Meyer SMA 8050 - v2	11.17	19.32	10.12	11.19	8.62
Inc 5/5/1 SMA 9150	20.30	21.65	22.03	20.34	24.77

B.2.2 No terrain, no clock, one-way dynamic (15 min).—Figure B.2.2.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with 15-min dynamic measurements). Table B.2.2.1 tabulates the weighted system availabilities from figure B.2.2.1. Table B.2.2.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

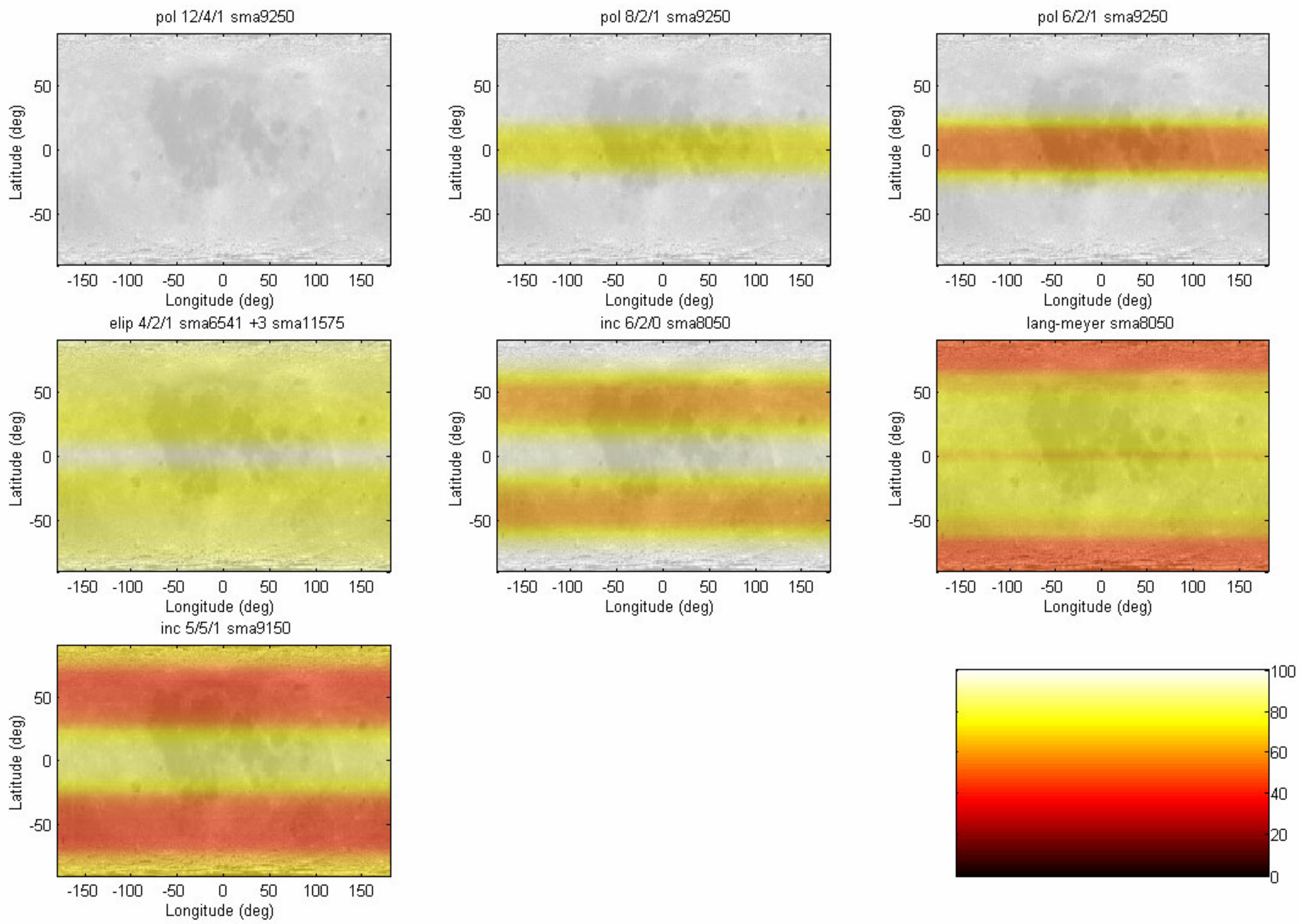

Figure B.2.2.1.—Lunar system availability results.

TABLE B.2.2.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	91.81	100.00	89.12	91.81	85.33
Pol 6/2/1 SMA 9250	82.53	100.00	76.82	82.53	68.76
Elip 4/2/1 SMA 6541 + 3 SMA 11575	81.33	88.15	80.82	81.33	81.60
Inc 6/2/0 SMA 8050	76.19	99.99	75.44	76.19	80.73
Lang-Meyer SMA 8050	71.38	46.83	75.47	71.37	75.36
Inc 5/5/1 SMA 9150	61.70	68.91	65.98	61.72	72.94

TABLE B.2.2.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.49	0.00	0.65	0.49	0.89
Pol 8/2/1 SMA 9250	10.50	9.97	10.76	10.48	11.14
Pol 6/2/1 SMA 9250	23.48	26.56	22.17	23.45	20.16
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	13.60	25.42	13.37	13.57	13.89
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	13.59	1.54	13.30	13.62	13.73
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	14.89	11.92	15.10	14.82	14.84
Inc 6/2/0 SMA 8050	22.76	30.94	22.30	22.85	23.71
Lang-Meyer SMA 8050 - v1	15.76	0.00	17.23	15.64	14.63
Lang-Meyer SMA 8050 - v2	16.34	22.60	16.22	16.41	15.73
Inc 5/5/1 SMA 9150	22.46	27.06	23.94	22.50	26.65

B.2.3 No terrain, no clock, one-way dynamic (1 hr).—Figure B.2.3.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with 1-hr dynamic measurements). Table B.2.3.1 tabulates the weighted system availabilities from figure B.2.3.1. Table B.2.3.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

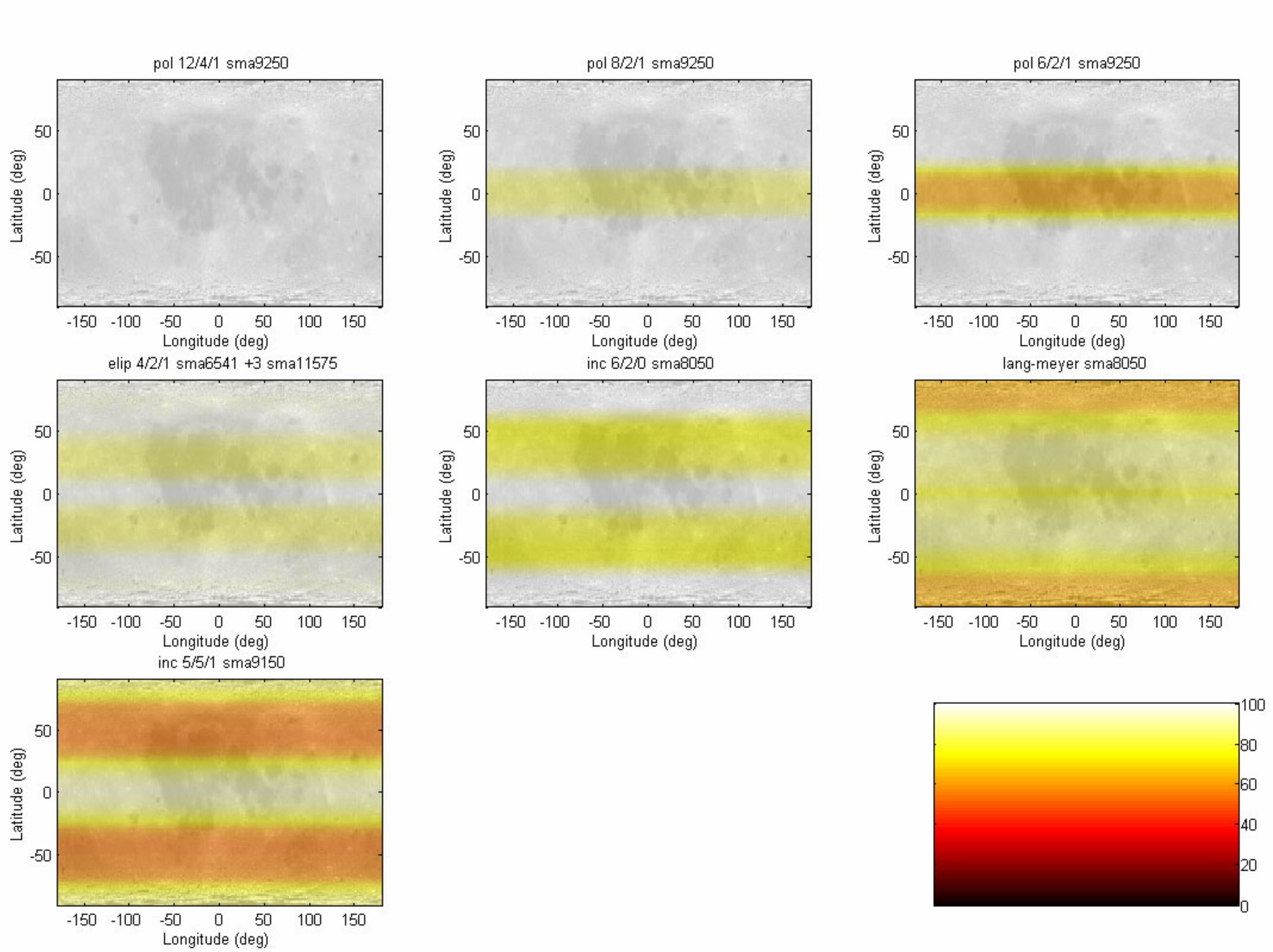

Figure B.2.3.1.—Lunar system availability results.

TABLE B.2.3.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	95.62	100.00	94.18	95.62	92.17
Pol 6/2/1 SMA 9250	87.29	100.00	83.14	87.29	77.15
Elip 4/2/1 SMA 6541 + 3 SMA 11575	91.37	97.57	89.49	91.36	89.65
Inc 6/2/0 SMA 8050	85.40	100.00	84.55	85.40	88.05
Lang-Meyer SMA 8050	81.53	63.49	85.20	81.52	84.92
Inc 5/5/1 SMA 9150	70.37	83.45	73.62	70.38	80.40

TABLE B.2.3.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.15	0.00	0.20	0.15	0.28
Pol 8/2/1 SMA 9250	5.85	0.00	6.91	5.85	8.13
Pol 6/2/1 SMA 9250	19.06	13.79	19.76	19.03	19.27
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	10.71	15.35	9.39	10.68	9.50
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	10.69	2.20	9.33	10.70	9.33
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	8.84	4.42	9.41	8.81	9.54
Inc 6/2/0 SMA 8050	19.00	23.38	18.73	19.09	18.89
Lang-Meyer SMA 8050 - v1	16.39	0.00	18.29	16.28	15.58
Lang-Meyer SMA 8050 - v2	15.46	30.87	14.63	15.51	13.59
Inc 5/5/1 SMA 9150	23.17	31.99	23.82	23.19	26.18

B.2.4 Good terrain, no clock, one-way kinematic.—Figure B.2.4.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with kinematic measurements). Table B.2.4.1 tabulates the weighted system availabilities from figure B.2.4.1. Table B.2.4.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

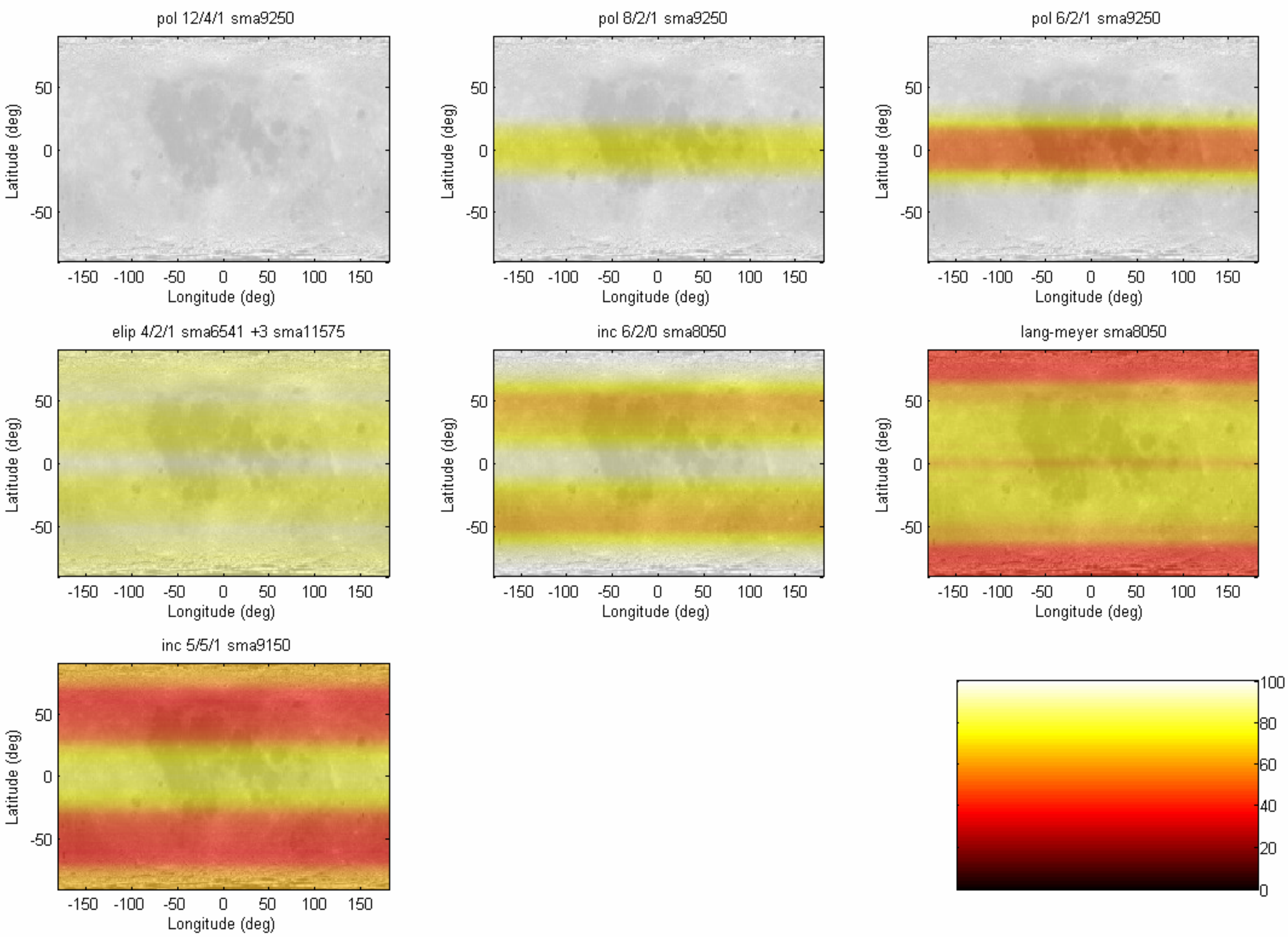

Figure B.2.4.1.—Lunar system availability results.

TABLE B.2.4.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	92.17	100.00	89.60	92.17	85.98
Pol 6/2/1 SMA 9250	81.11	100.00	74.94	81.11	66.44
Elip 4/2/1 SMA 6541 + 3 SMA 11575	84.44	87.72	83.23	84.43	83.39
Inc 6/2/0 SMA 8050	76.79	98.59	76.32	76.80	80.48
Lang-Meyer SMA 8050	67.33	41.27	71.55	67.31	71.69
Inc 5/5/1 SMA 9150	58.24	63.19	62.82	58.27	69.75

TABLE B.2.4.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.67	0.00	0.89	0.67	1.21
Pol 8/2/1 SMA 9250	9.15	1.08	10.12	9.14	11.03
Pol 6/2/1 SMA 9250	22.75	22.65	22.11	22.71	20.06
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	13.98	31.30	12.57	13.94	12.37
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	13.95	1.17	12.46	13.97	12.13
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	17.03	11.23	18.20	16.95	18.78
Inc 6/2/0 SMA 8050	22.49	30.82	22.11	22.59	23.09
Lang-Meyer SMA 8050 - v1	15.50	0.00	16.89	15.37	14.48
Lang-Meyer SMA 8050 - v2	16.52	20.36	16.57	16.58	16.30
Inc 5/5/1 SMA 9150	22.05	25.22	23.75	22.10	26.52

B.2.5 Good terrain, no clock, one-way dynamic (15 min).—Figure B.2.5.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with 15-min dynamic measurements). Table B.2.5.1 tabulates the weighted system availabilities from figure B.2.5.1. Table B.2.5.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

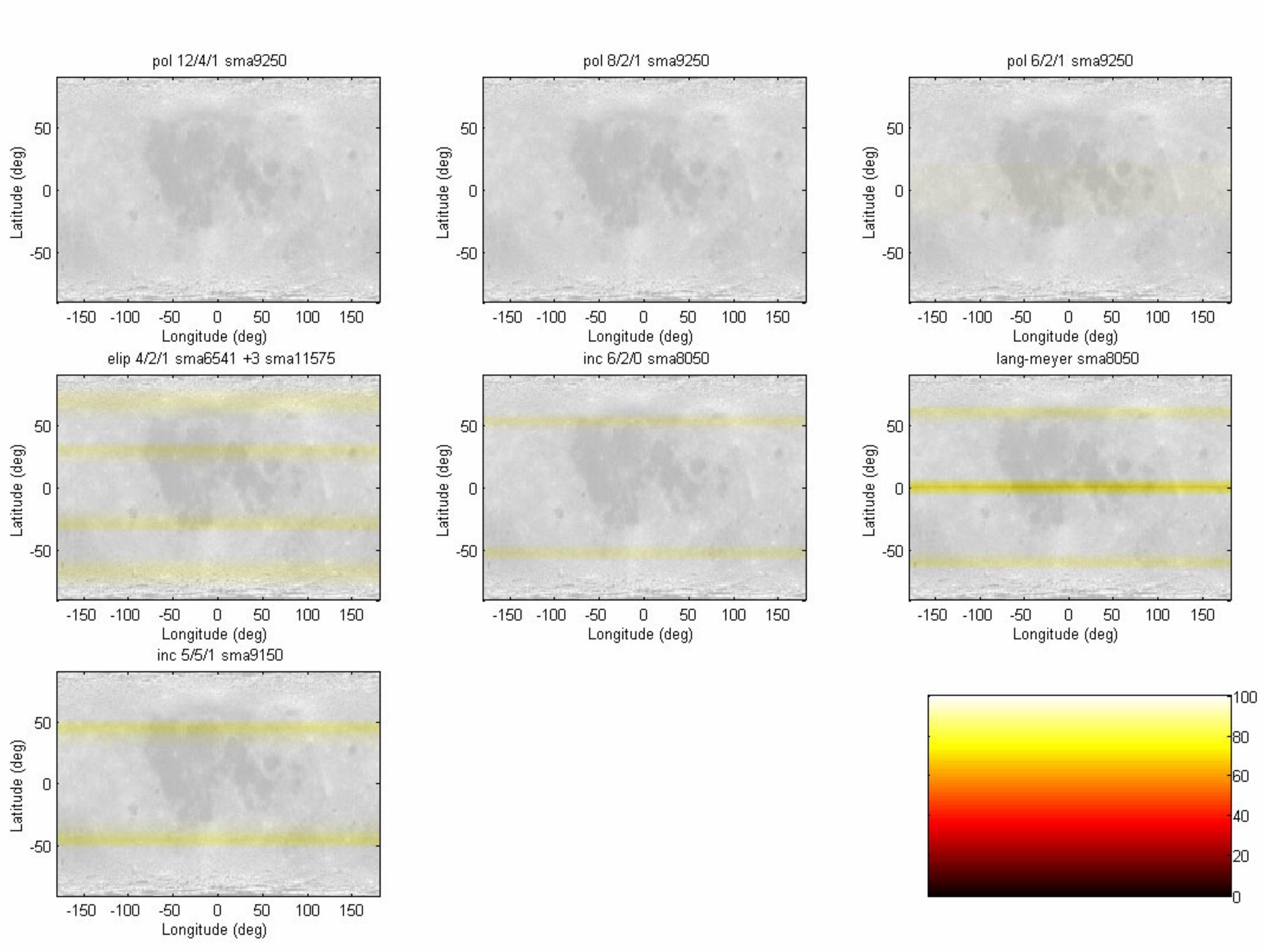

Figure B.2.5.1.—Lunar system availability results.

TABLE B.2.5.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.49	100.00	99.32	99.49	99.07
Pol 6/2/1 SMA 9250	99.08	100.00	98.78	99.09	98.37
Elip 4/2/1 SMA 6541 + 3 SMA 11575	97.18	100.00	97.53	97.18	96.65
Inc 6/2/0 SMA 8050	99.11	100.00	99.89	99.11	100.00
Lang-Meyer SMA 8050	96.90	100.00	97.08	96.89	96.24
Inc 5/5/1 SMA 9150	97.71	100.00	96.96	97.71	99.55

TABLE B.2.5.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.08	0.05	1.39	1.06	1.79
Pol 6/2/1 SMA 9250	3.23	2.43	4.03	3.20	5.23
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.37	5.23	0.86	1.36	0.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.36	0.00	0.85	1.36	0.87
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.69	0.00	4.63	3.69	4.46
Inc 6/2/0 SMA 8050	3.71	0.02	3.95	3.74	3.28
Lang-Meyer SMA 8050 - v1	4.94	0.00	6.45	4.90	7.86
Lang-Meyer SMA 8050 - v2	4.49	13.63	2.76	4.51	1.84
Inc 5/5/1 SMA 9150	7.88	6.62	6.99	7.88	6.15

***B.2.6 Good terrain, no clock, one-way dynamic (1 hr)*.**—Figure B.2.6.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with 1-hr dynamic measurements). Table B.2.6.1 tabulates the weighted system availabilities from figure B.2.6.1. Table B.2.6.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

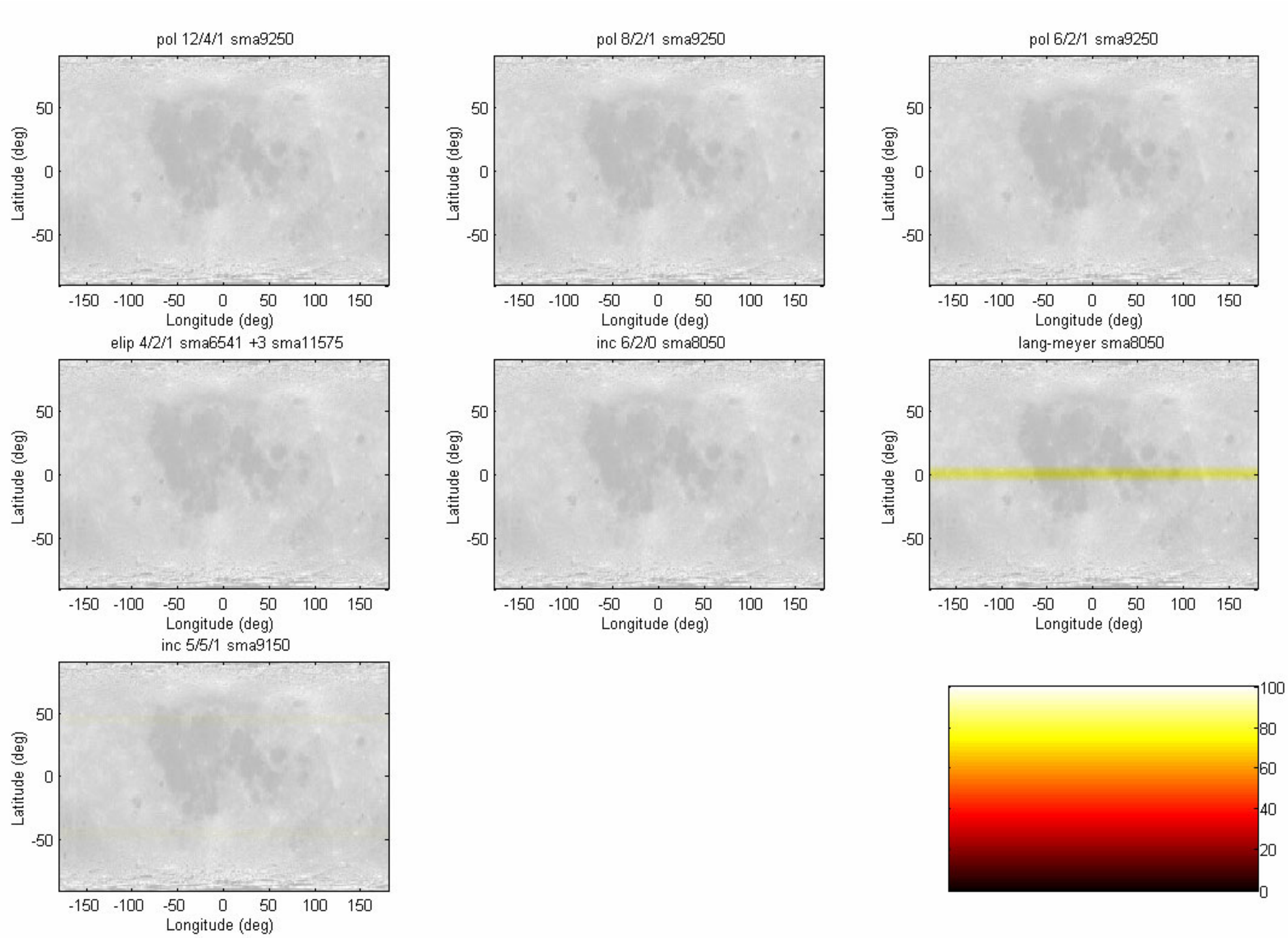

Figure B.2.6.1.—Lunar system availability results.

TABLE B.2.6.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.95	100.00	99.94	99.95	99.93
Pol 6/2/1 SMA 9250	99.89	100.00	99.85	99.89	99.80
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.93	100.00	99.98	99.93	99.98
Inc 6/2/0 SMA 8050	99.89	100.00	99.99	99.88	100.00
Lang-Meyer SMA 8050	98.33	100.00	97.91	98.33	97.19
Inc 5/5/1 SMA 9150	99.63	100.00	99.51	99.63	99.96

TABLE B.2.6.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.59	0.00	0.80	0.58	1.08
Pol 6/2/1 SMA 9250	2.23	0.25	2.94	2.22	3.95
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.42	1.54	0.18	0.41	0.12
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.41	0.00	0.17	0.41	0.10
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.60	0.00	3.44	2.61	3.45
Inc 6/2/0 SMA 8050	2.57	0.00	2.69	2.59	2.10
Lang-Meyer SMA 8050 - v1	2.69	0.00	3.56	2.66	4.73
Lang-Meyer SMA 8050 - v2	3.16	9.52	1.67	3.17	1.00
Inc 5/5/1 SMA 9150	6.16	3.60	5.50	6.17	4.17

B.2.7 No terrain, 3-hr clock synchronization, one-way kinematic.—Figure B.2.7.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with kinematic measurements). Table B.2.7.1 tabulates the weighted system availabilities from figure B.2.7.1. Table B.2.7.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

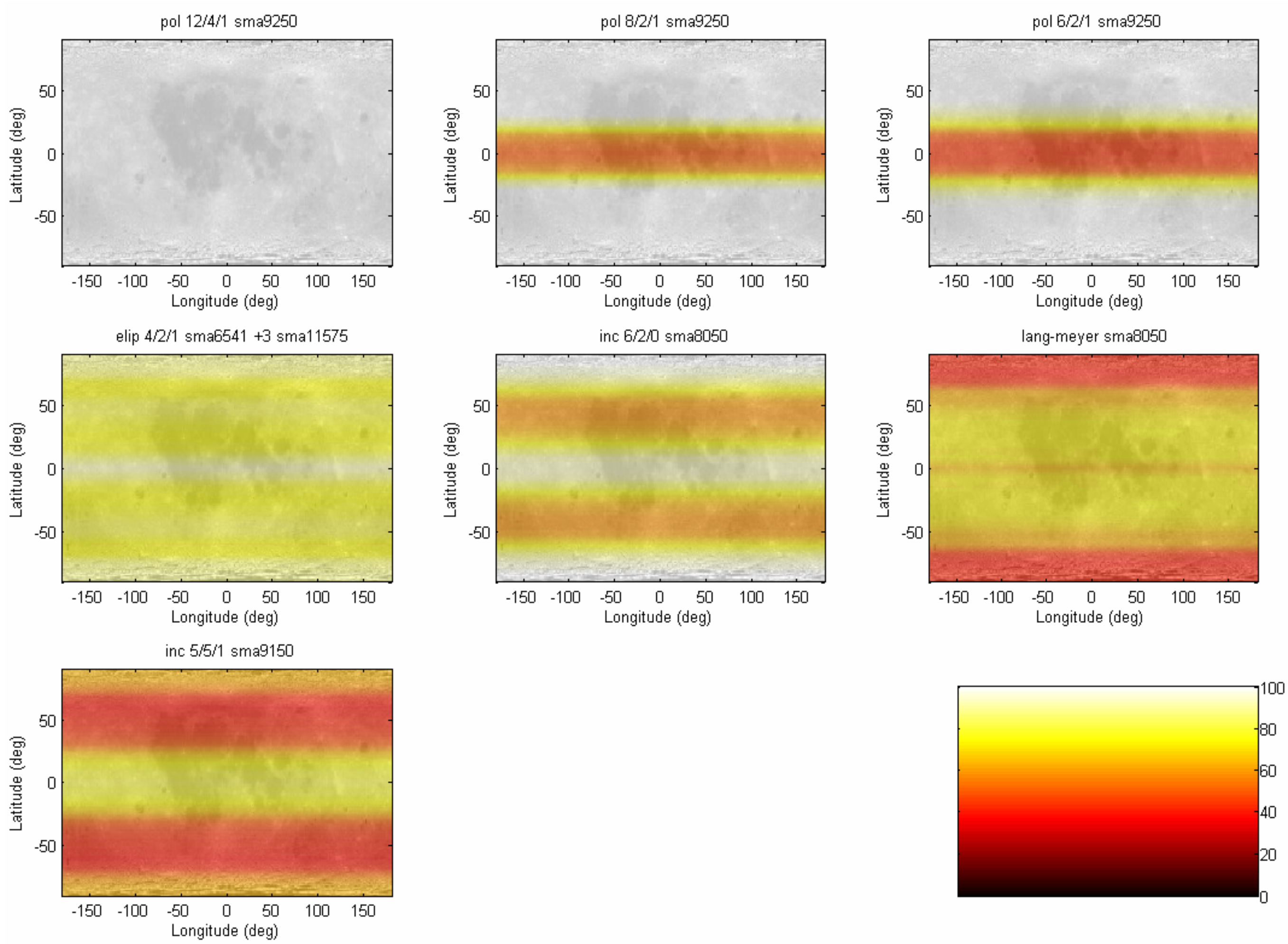

Figure B.2.7.1.—Lunar system availability results.

TABLE B.2.7.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	84.06	100.00	78.84	84.06	71.44
Pol 6/2/1 SMA 9250	78.28	99.92	71.18	78.30	61.64
Elip 4/2/1 SMA 6541 + 3 SMA 11575	79.19	87.72	79.48	79.20	79.52
Inc 6/2/0 SMA 8050	74.32	98.59	73.76	74.33	79.03
Lang-Meyer SMA 8050	67.31	41.27	71.54	67.28	71.66
Inc 5/5/1 SMA 9150	58.23	63.19	62.82	58.27	69.75

TABLE B.2.7.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.67	0.00	0.89	0.67	1.21
Pol 8/2/1 SMA 9250	9.46	11.33	9.08	9.45	8.77
Pol 6/2/1 SMA 9250	23.01	27.65	21.44	22.99	18.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	13.73	31.30	13.83	13.72	13.94
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	13.74	1.18	13.77	13.78	13.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	16.70	11.23	17.45	16.63	17.48
Inc 6/2/0 SMA 8050	22.54	30.82	22.23	22.65	23.62
Lang-Meyer SMA 8050 - v1	15.58	0.00	17.04	15.43	14.72
Lang-Meyer SMA 8050 - v2	16.51	20.36	16.56	16.55	16.31
Inc 5/5/1 SMA 9150	22.05	25.22	23.76	22.12	26.52

B.2.8 No terrain, 3-hr clock synchronization, one-way dynamic (15 min).—Figure B.2.8.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with 15-min dynamic measurements). Table B.2.8.1 tabulates the weighted system availabilities from figure B.2.8.1. Table B.2.8.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

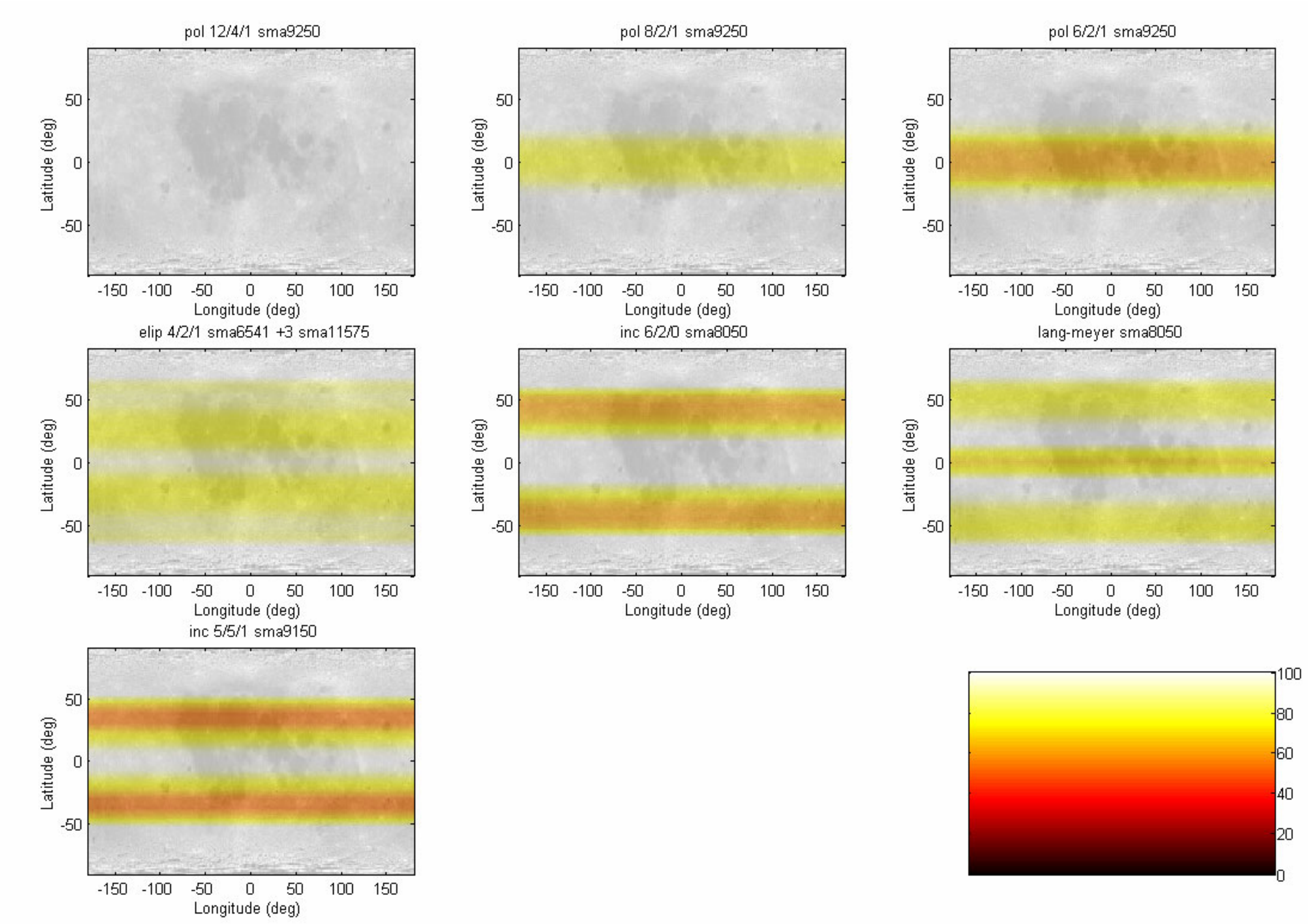

Figure B.2.8.1.—Lunar system availability results.

TABLE B.2.8.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	93.09	100.00	90.83	93.09	87.58
Pol 6/2/1 SMA 9250	86.65	100.00	82.27	86.66	76.05
Elip 4/2/1 SMA 6541 + 3 SMA 11575	85.40	100.00	82.87	85.40	82.34
Inc 6/2/0 SMA 8050	84.01	100.00	82.34	84.02	89.84
Lang-Meyer SMA 8050	86.92	99.83	86.92	86.93	89.25
Inc 5/5/1 SMA 9150	80.00	99.99	73.55	80.03	78.30

TABLE B.2.8.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.14	0.00	0.19	0.14	0.26
Pol 8/2/1 SMA 9250	3.29	4.10	3.22	3.27	3.46
Pol 6/2/1 SMA 9250	7.69	17.70	5.77	7.73	5.03
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	8.35	5.37	9.46	8.33	11.30
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	8.35	0.02	9.42	8.34	11.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.77	0.00	3.49	2.75	2.84
Inc 6/2/0 SMA 8050	5.57	0.02	6.36	5.74	6.97
Lang-Meyer SMA 8050 - v1	8.56	0.00	10.35	8.48	8.92
Lang-Meyer SMA 8050 - v2	5.48	13.64	4.61	5.54	5.37
Inc 5/5/1 SMA 9150	11.10	6.61	10.78	11.19	12.41

B.2.9 No terrain, 3-hr clock synchronization, one-way dynamic (1 hr).—Figure B.2.9.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with 1-hr dynamic measurements). Table B.2.9.1 tabulates the weighted system availabilities from figure B.2.9.1. Table B.2.9.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

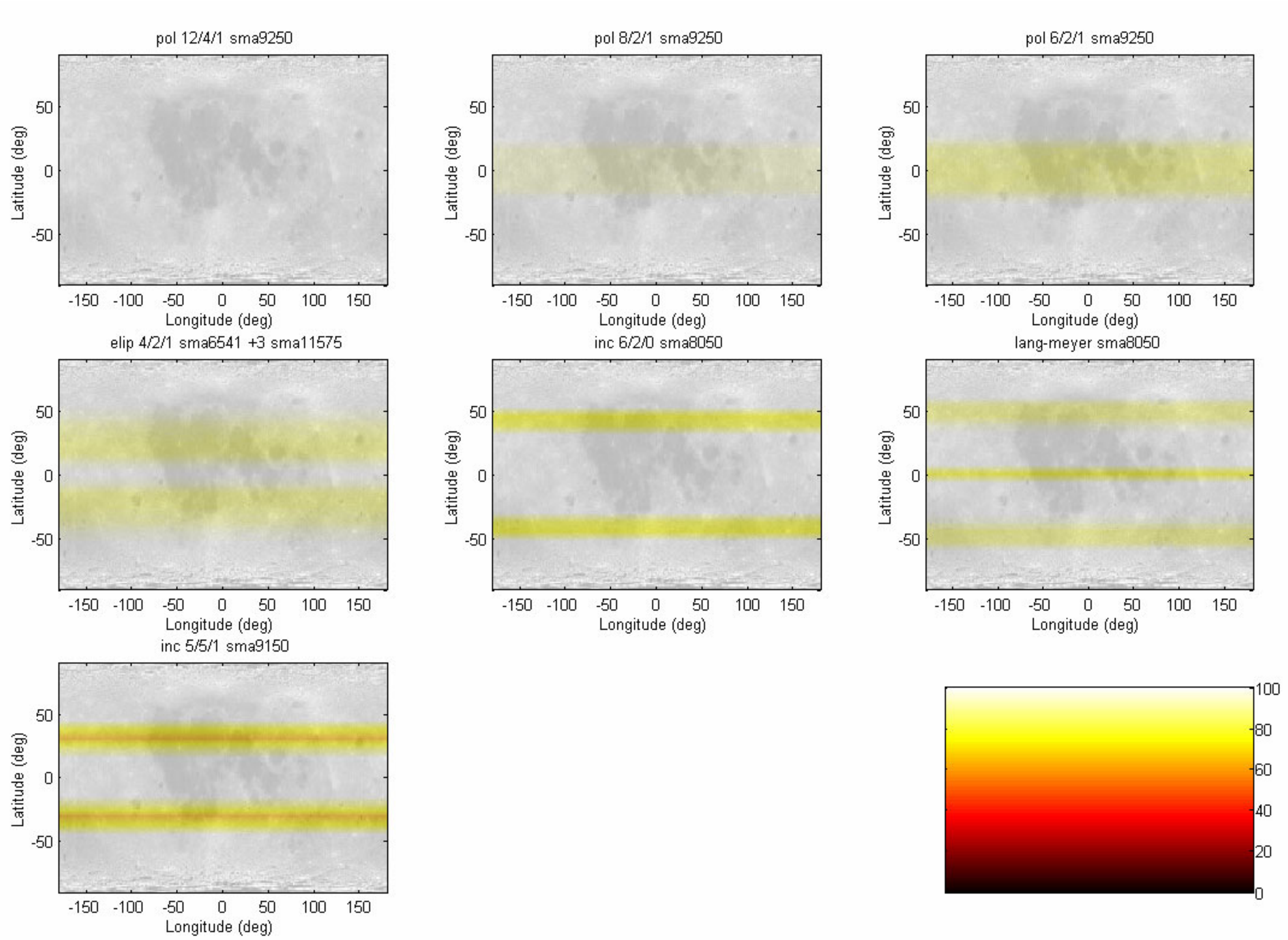

Figure B.2.9.1.—Lunar system availability results.

TABLE B.2.9.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	98.26	100.00	97.69	98.26	96.86
Pol 6/2/1 SMA 9250	95.54	100.00	94.08	95.54	91.99
Elip 4/2/1 SMA 6541 + 3 SMA 11575	93.42	100.00	91.45	93.40	90.79
Inc 6/2/0 SMA 8050	95.55	100.00	94.10	95.56	100.00
Lang-Meyer SMA 8050	95.63	99.94	95.56	95.65	97.11
Inc 5/5/1 SMA 9150	91.35	100.00	88.53	91.38	88.94

TABLE B.2.9.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.71	0.00	2.05	1.72	2.52
Pol 6/2/1 SMA 9250	4.33	2.43	4.26	4.36	4.82
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	3.06	1.59	2.95	3.05	3.67
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	3.04	0.00	2.97	2.98	3.57
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	1.66	0.00	2.22	1.64	2.48
Inc 6/2/0 SMA 8050	4.32	0.00	4.65	4.44	4.48
Lang-Meyer SMA 8050 - v1	6.15	0.00	7.68	6.08	7.42
Lang-Meyer SMA 8050 - v2	3.21	9.53	1.97	3.25	1.92
Inc 5/5/1 SMA 9150	8.15	3.60	7.90	8.23	7.51

B.2.10 Good terrain, 3-hr clock synchronization, one-way kinematic.—Figure B.2.10.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with kinematic measurements). Table B.2.10.1 tabulates the weighted system availabilities from figure B.2.10.1. Table B.2.10.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

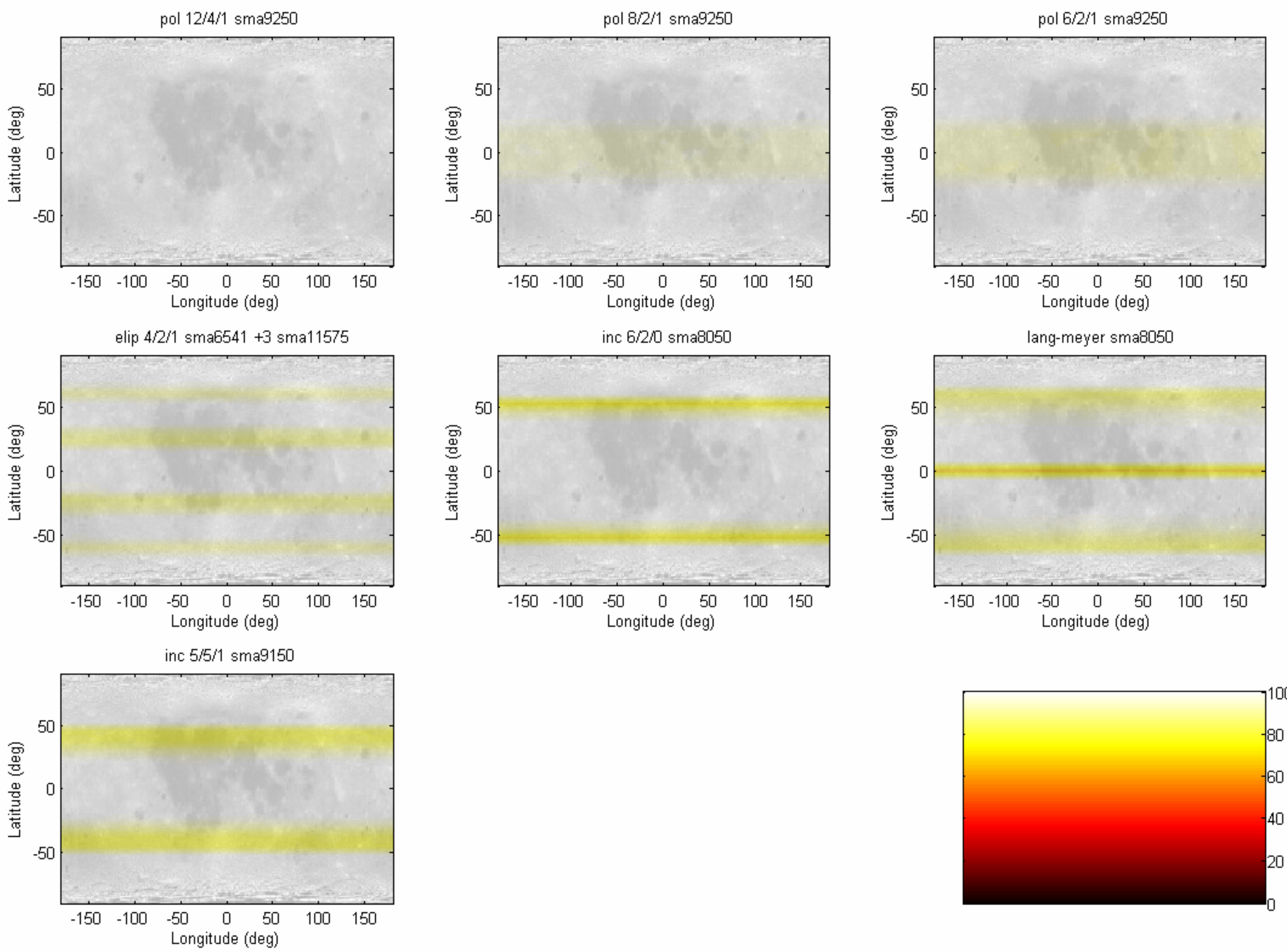

Figure B.2.10.1.—Lunar system availability results.

TABLE B.2.10.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	98.14	100.00	97.54	98.14	96.66
Pol 6/2/1 SMA 9250	96.94	100.00	95.94	96.94	94.60
Elip 4/2/1 SMA 6541 + 3 SMA 11575	95.98	100.00	95.84	95.96	94.41
Inc 6/2/0 SMA 8050	96.74	100.00	98.69	96.76	100.00
Lang-Meyer SMA 8050	94.91	99.79	95.99	94.94	95.80
Inc 5/5/1 SMA 9150	94.57	99.98	92.79	94.64	97.47

TABLE B.2.10.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.01	0.00
Pol 8/2/1 SMA 9250	1.57	0.49	1.81	1.59	2.22
Pol 6/2/1 SMA 9250	5.20	7.74	5.84	5.32	7.19
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.80	6.28	1.16	1.79	1.17
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.80	0.04	1.12	1.80	1.08
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	5.60	0.00	7.36	5.53	6.85
Inc 6/2/0 SMA 8050	5.58	0.23	6.41	5.75	5.41
Lang-Meyer SMA 8050 - v1	6.35	0.00	8.10	6.23	9.17
Lang-Meyer SMA 8050 - v2	4.96	14.53	3.43	5.04	2.66
Inc 5/5/1 SMA 9150	8.81	7.36	7.63	9.01	7.41

B.2.11 Good terrain, 3-hr clock synchronization, one-way dynamic (15 min).—Figure B.2.11.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with 15-min dynamic measurements). Table B.2.11.1 tabulates the weighted system availabilities from figure B.2.11.1. Table B.2.11.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

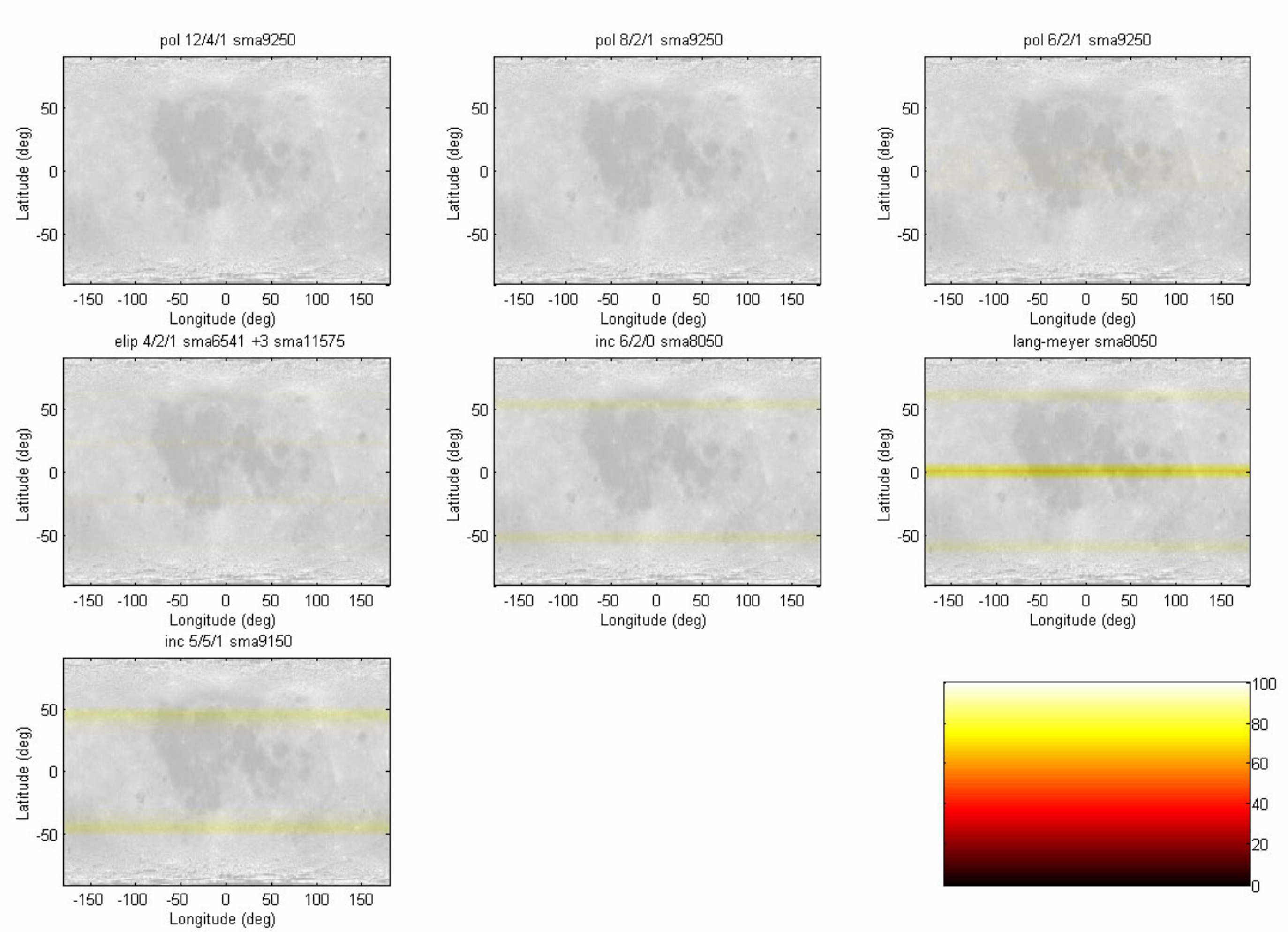

Figure B.2.11.1.—Lunar system availability results.

TABLE B.2.11.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.58	100.00	99.45	99.59	99.27
Pol 6/2/1 SMA 9250	99.37	100.00	99.17	99.37	98.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.44	100.00	99.44	99.43	99.23
Inc 6/2/0 SMA 8050	99.38	100.00	99.94	99.38	100.00
Lang-Meyer SMA 8050	97.23	100.00	97.11	97.23	96.24
Inc 5/5/1 SMA 9150	98.40	100.00	97.88	98.40	99.63

TABLE B.2.11.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.93	0.00	1.23	0.92	1.63
Pol 6/2/1 SMA 9250	2.91	0.56	3.79	2.90	5.04
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.05	4.74	0.55	1.05	0.48
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.05	0.00	0.54	1.05	0.48
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.59	0.00	4.71	3.60	4.85
Inc 6/2/0 SMA 8050	3.55	0.00	3.75	3.58	3.08
Lang-Meyer SMA 8050 - v1	4.56	0.00	5.99	4.53	7.43
Lang-Meyer SMA 8050 - v2	4.38	13.16	2.63	4.40	1.72
Inc 5/5/1 SMA 9150	7.68	6.22	6.83	7.68	5.81

B.2.12 Good terrain, 3-hr clock synchronization, one-way dynamic (1 hr).—Figure B.2.12.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with 1-hr dynamic measurements). Table B.2.12.1 tabulates the weighted system availabilities from figure B.2.12.1. Table B.2.12.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

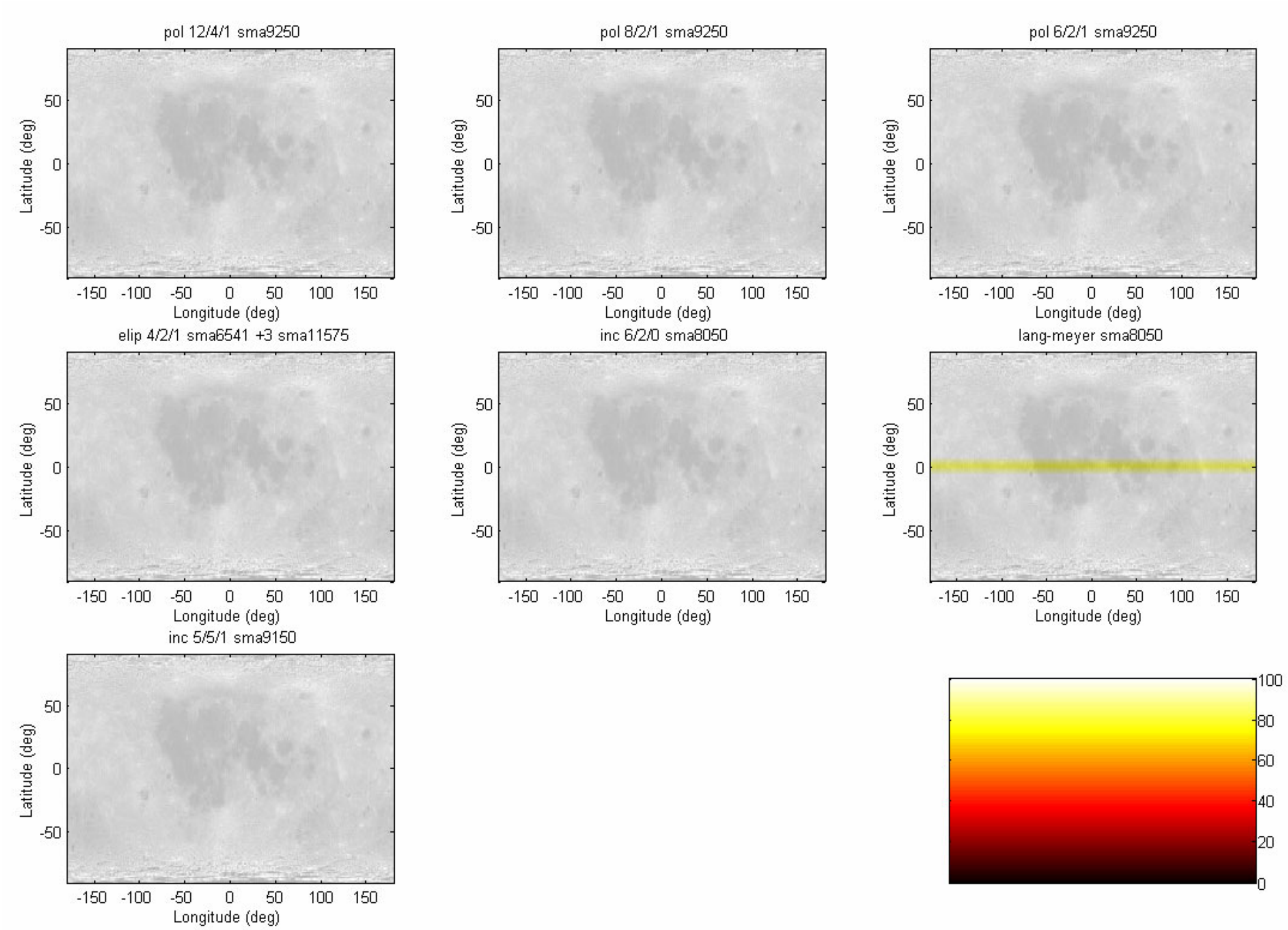

Figure B.2.12.1.—Lunar system availability results.

TABLE B.2.12.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.96	100.00	99.95	99.96	99.93
Pol 6/2/1 SMA 9250	99.95	100.00	99.93	99.95	99.92
Elip 4/2/1 SMA 6541 + 3 SMA 11575	100.00	100.00	100.00	100.00	100.00
Inc 6/2/0 SMA 8050	100.00	100.00	100.00	100.00	100.00
Lang-Meyer SMA 8050	98.43	100.00	97.92	98.43	97.19
Inc 5/5/1 SMA 9150	99.98	100.00	99.97	99.98	99.98

TABLE B.2.12.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.52	0.00	0.71	0.52	0.97
Pol 6/2/1 SMA 9250	2.11	0.00	2.81	2.10	3.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.25	1.25	0.11	0.25	0.03
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.25	0.00	0.10	0.25	0.02
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.50	0.00	3.31	2.50	3.32
Inc 6/2/0 SMA 8050	2.47	0.00	2.57	2.50	2.01
Lang-Meyer SMA 8050 - v1	2.44	0.00	3.27	2.42	4.36
Lang-Meyer SMA 8050 - v2	3.03	9.05	1.58	3.05	0.93
Inc 5/5/1 SMA 9150	5.99	3.31	5.35	5.99	3.95

B.2.13 No terrain, two-way kinematic.—Figure B.2.13.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with kinematic measurements). Table B.2.13.1 tabulates the weighted system availabilities from figure B.2.13.1. Table B.2.13.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

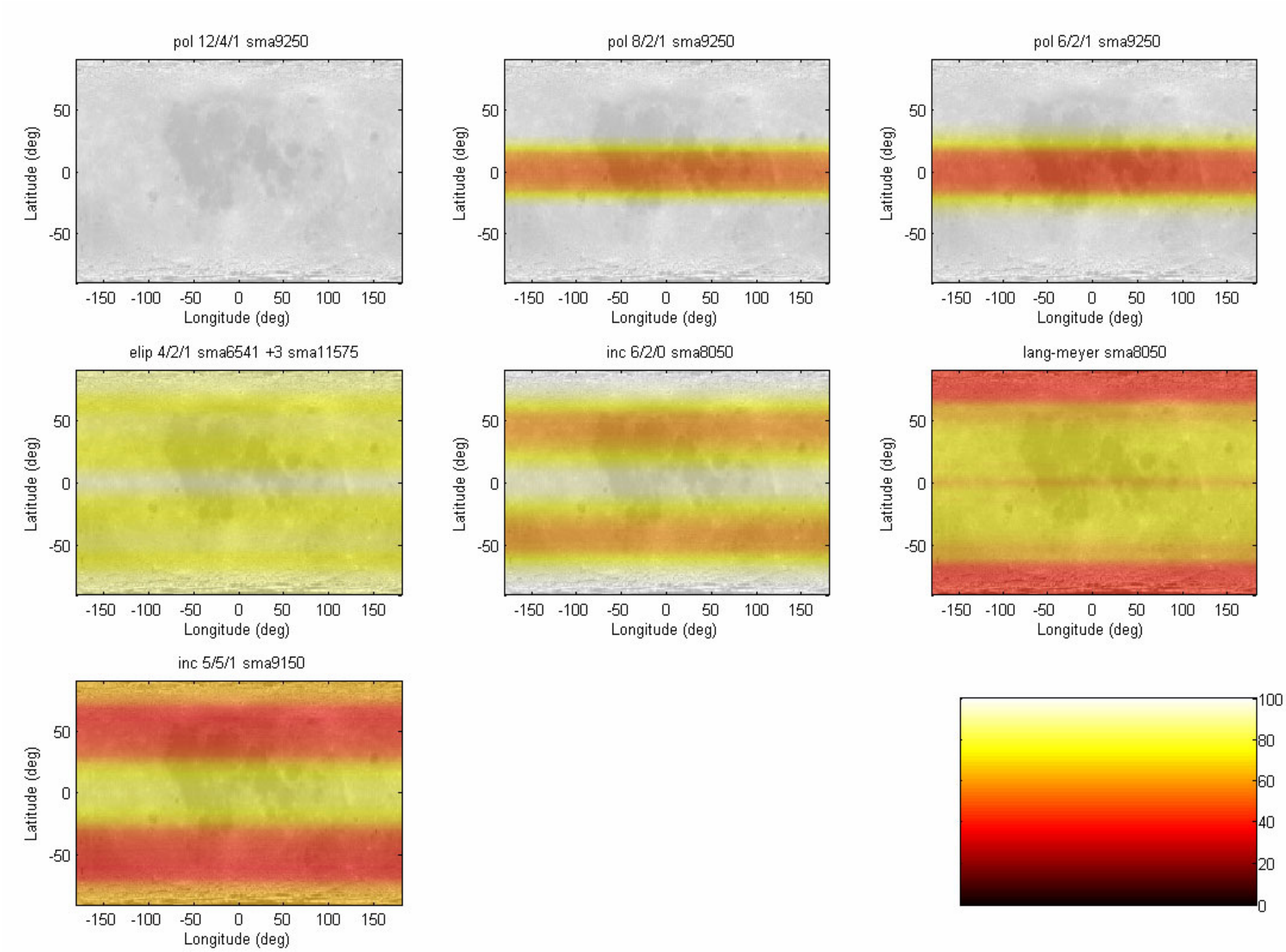

Figure B.2.13.1.—Lunar system availability results.

TABLE B.2.13.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	84.19	100.00	79.00	84.20	71.74
Pol 6/2/1 SMA 9250	78.45	100.00	71.40	78.45	61.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575	79.34	87.72	79.51	79.34	79.58
Inc 6/2/0 SMA 8050	74.70	98.59	74.26	74.71	79.69
Lang-Meyer SMA 8050	67.33	41.27	71.55	67.31	71.69
Inc 5/5/1 SMA 9150	58.24	63.19	62.82	58.27	69.75

TABLE B.2.13.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.67	0.00	0.89	0.67	1.21
Pol 8/2/1 SMA 9250	9.44	11.31	9.06	9.42	8.77
Pol 6/2/1 SMA 9250	23.01	27.65	21.45	22.97	18.81
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	13.80	31.30	13.84	13.77	13.98
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	13.79	1.17	13.75	13.82	13.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	16.70	11.23	17.45	16.63	17.50
Inc 6/2/0 SMA 8050	22.65	30.82	22.39	22.75	23.84
Lang-Meyer SMA 8050 - v1	15.49	0.00	16.88	15.36	14.47
Lang-Meyer SMA 8050 - v2	16.52	20.36	16.56	16.58	16.30
Inc 5/5/1 SMA 9150	22.05	25.22	23.75	22.10	26.52

B.2.14 No terrain, two-way dynamic (15 min).—Figure B.2.14.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with 15-min dynamic measurements). Table B.2.14.1 tabulates the weighted system availabilities from figure B.2.14.1. Table B.2.14.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

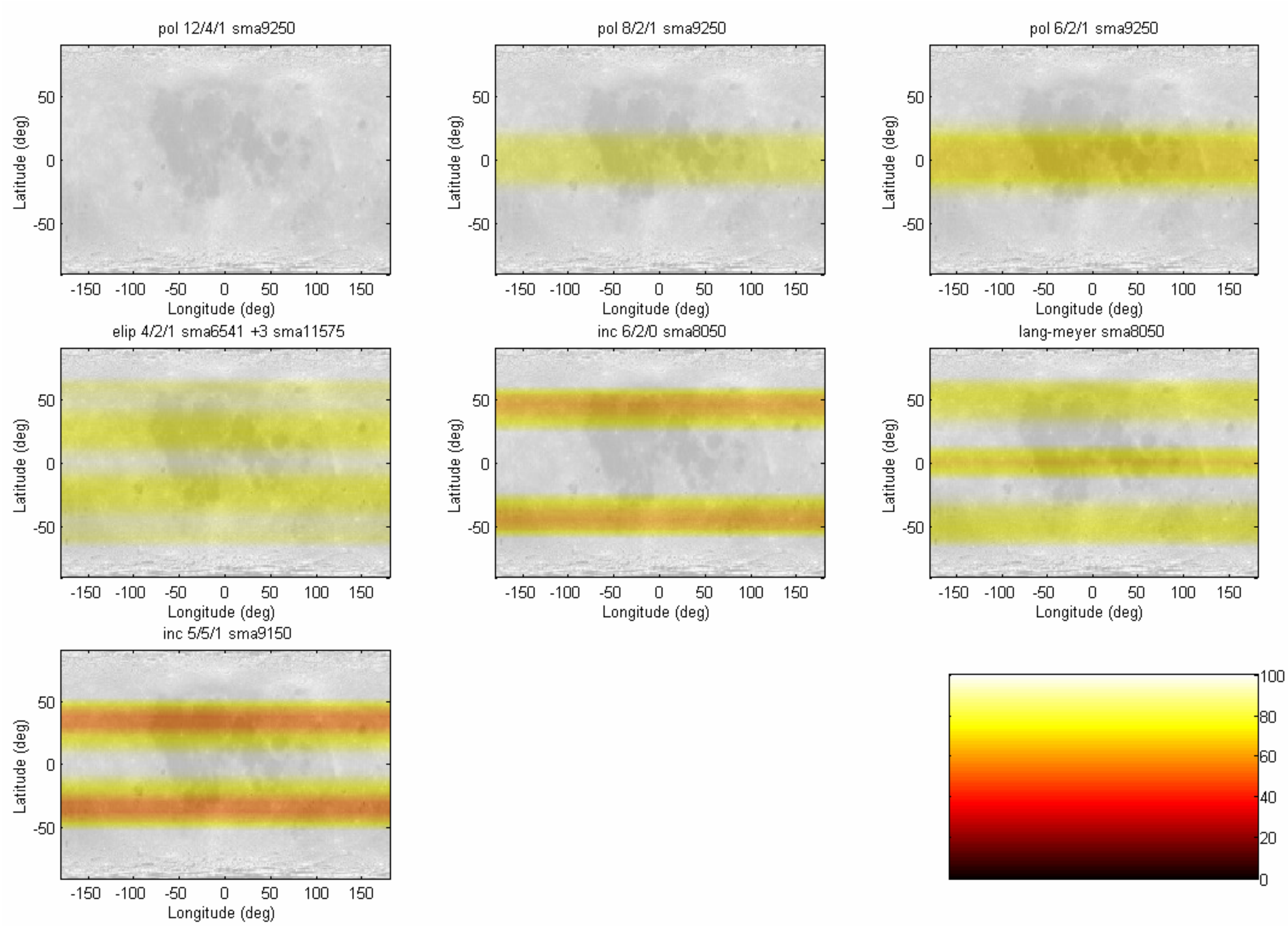

Figure B.2.14.1.—Lunar system availability results.

TABLE B.2.14.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	93.97	100.00	92.00	93.98	89.19
Pol 6/2/1 SMA 9250	88.59	100.00	84.85	88.58	79.55
Elip 4/2/1 SMA 6541 + 3 SMA 11575	85.92	100.00	83.56	85.92	82.35
Inc 6/2/0 SMA 8050	87.59	100.00	87.06	87.59	95.37
Lang-Meyer SMA 8050	86.96	100.00	86.95	86.95	89.33
Inc 5/5/1 SMA 9150	80.05	100.00	73.57	80.07	78.31

TABLE B.2.14.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.14	0.00	0.19	0.14	0.26
Pol 8/2/1 SMA 9250	3.36	4.10	3.31	3.35	3.60
Pol 6/2/1 SMA 9250	8.12	17.70	6.43	8.07	5.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	8.31	5.52	9.42	8.27	11.30
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	8.31	0.00	9.36	8.32	11.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.15	0.00	4.00	3.14	2.87
Inc 6/2/0 SMA 8050	6.80	0.02	8.17	6.84	8.96
Lang-Meyer SMA 8050 - v1	8.65	0.00	10.47	8.58	9.00
Lang-Meyer SMA 8050 - v2	5.50	13.64	4.65	5.52	5.42
Inc 5/5/1 SMA 9150	11.13	6.62	10.91	11.14	12.58

B.2.15 No terrain, two-way dynamic (1 hr).—Figure B.2.15.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with 1-hr dynamic measurements). Table B.2.15.1 tabulates the weighted system availabilities from figure B.2.15.1. Table B.2.15.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

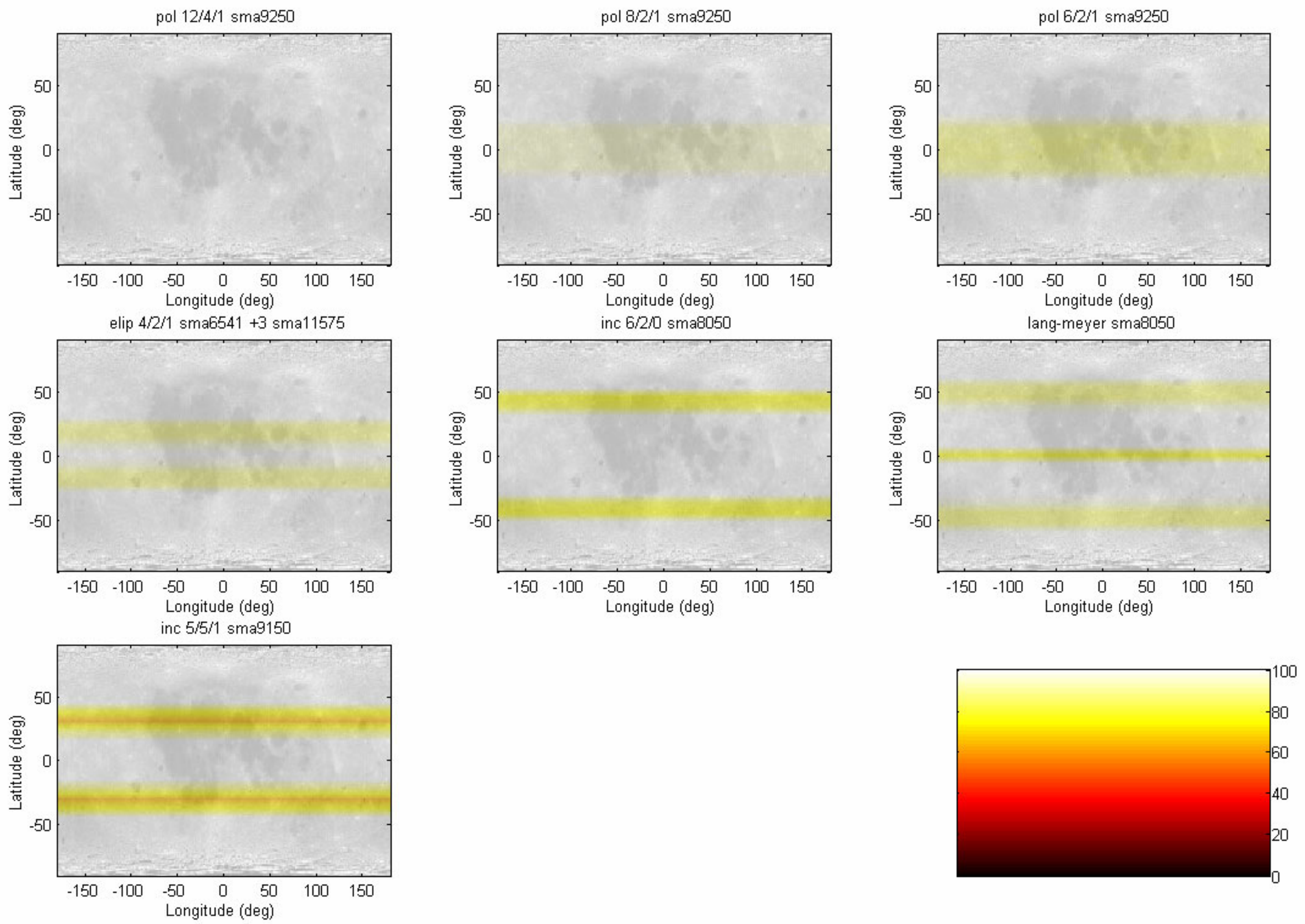

Figure B.2.15.1.—Lunar system availability results.

TABLE B.2.15.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	98.26	100.00	97.69	98.26	96.87
Pol 6/2/1 SMA 9250	95.56	100.00	94.11	95.56	92.03
Elip 4/2/1 SMA 6541 + 3 SMA 11575	96.34	100.00	95.31	96.34	93.76
Inc 6/2/0 SMA 8050	95.58	100.00	94.13	95.58	100.00
Lang-Meyer SMA 8050	95.66	100.00	95.58	95.65	97.14
Inc 5/5/1 SMA 9150	91.41	100.00	88.59	91.41	88.98

TABLE B.2.15.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.72	0.00	2.08	1.72	2.57
Pol 6/2/1 SMA 9250	4.14	2.43	4.06	4.12	4.50
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.92	1.63	2.79	2.89	3.59
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.89	0.00	2.73	2.88	3.49
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.88	0.00	3.84	2.87	3.65
Inc 6/2/0 SMA 8050	4.16	0.00	4.58	4.19	4.38
Lang-Meyer SMA 8050 - v1	6.20	0.00	7.72	6.14	7.46
Lang-Meyer SMA 8050 - v2	3.20	9.53	1.99	3.21	1.95
Inc 5/5/1 SMA 9150	8.15	3.60	8.00	8.14	7.63

B.2.16 Good terrain, two-way kinematic.—Figure B.2.16.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with kinematic measurements). Table B.2.16.1 tabulates the weighted system availabilities from figure B.2.16.1. Table B.2.16.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

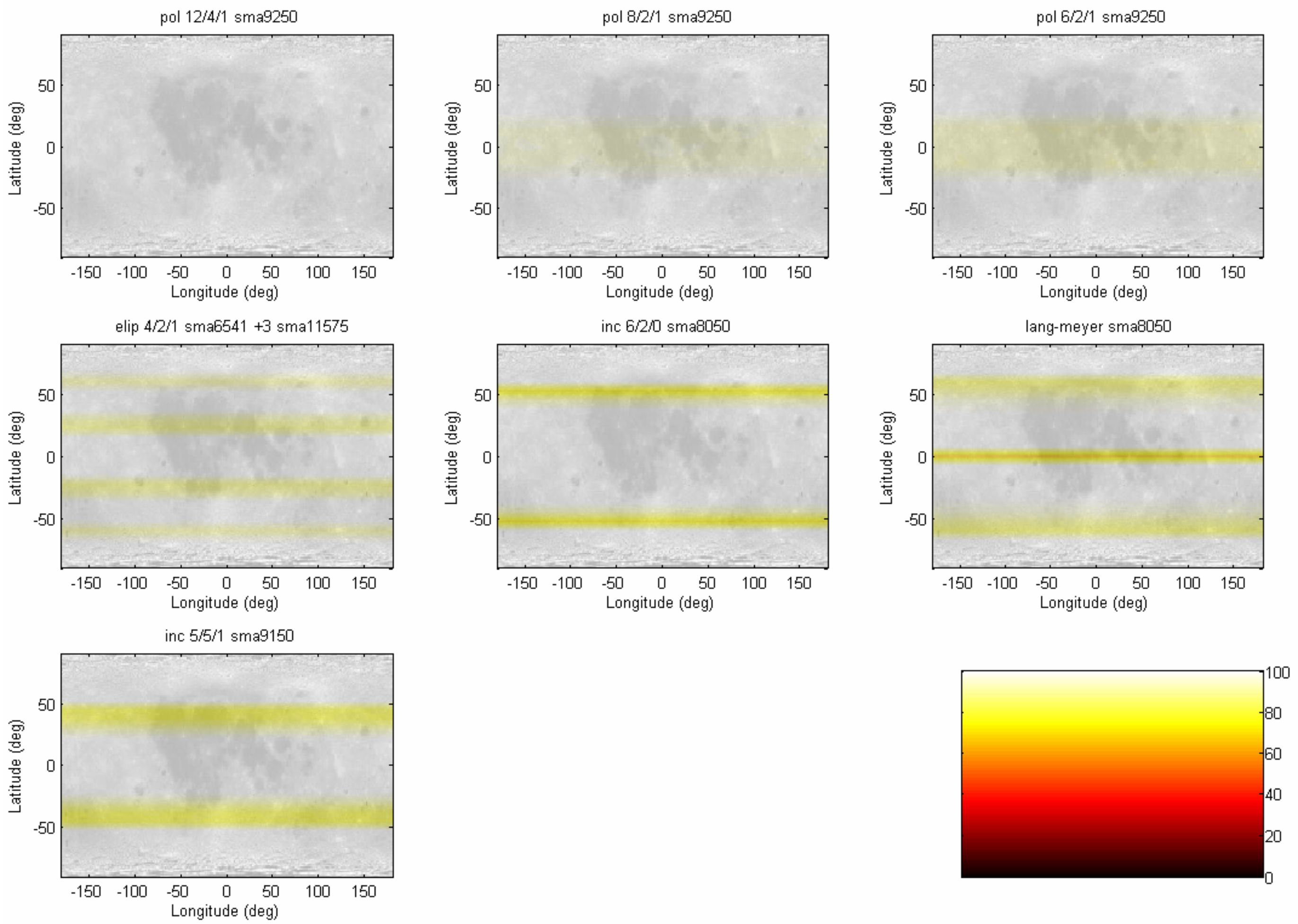

Figure B.2.16.1.—Lunar system availability results.

TABLE B.2.16.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	98.16	100.00	97.55	98.15	96.71
Pol 6/2/1 SMA 9250	96.99	100.00	96.01	97.00	94.66
Elip 4/2/1 SMA 6541 + 3 SMA 11575	96.03	100.00	95.88	96.02	94.46
Inc 6/2/0 SMA 8050	96.81	100.00	98.79	96.81	100.00
Lang-Meyer SMA 8050	94.97	100.00	96.06	94.97	95.89
Inc 5/5/1 SMA 9150	94.69	100.00	92.95	94.70	97.67

TABLE B.2.16.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.55	0.49	1.80	1.53	2.22
Pol 6/2/1 SMA 9250	4.02	7.74	4.43	4.03	5.40
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.77	6.28	1.10	1.76	1.14
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.77	0.00	1.08	1.77	1.09
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.80	0.00	4.89	3.78	4.60
Inc 6/2/0 SMA 8050	4.70	0.23	5.38	4.74	4.71
Lang-Meyer SMA 8050 - v1	6.19	0.00	7.85	6.13	8.98
Lang-Meyer SMA 8050 - v2	4.88	14.53	3.43	4.90	2.66
Inc 5/5/1 SMA 9150	8.42	7.37	7.52	8.43	7.40

B.2.17 Good terrain, two-way dynamic (15 min).—Figure B.2.17.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with 15-min dynamic measurements). Table B.2.17.1 tabulates the weighted system availabilities from figure B.2.17.1. Table B.2.17.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

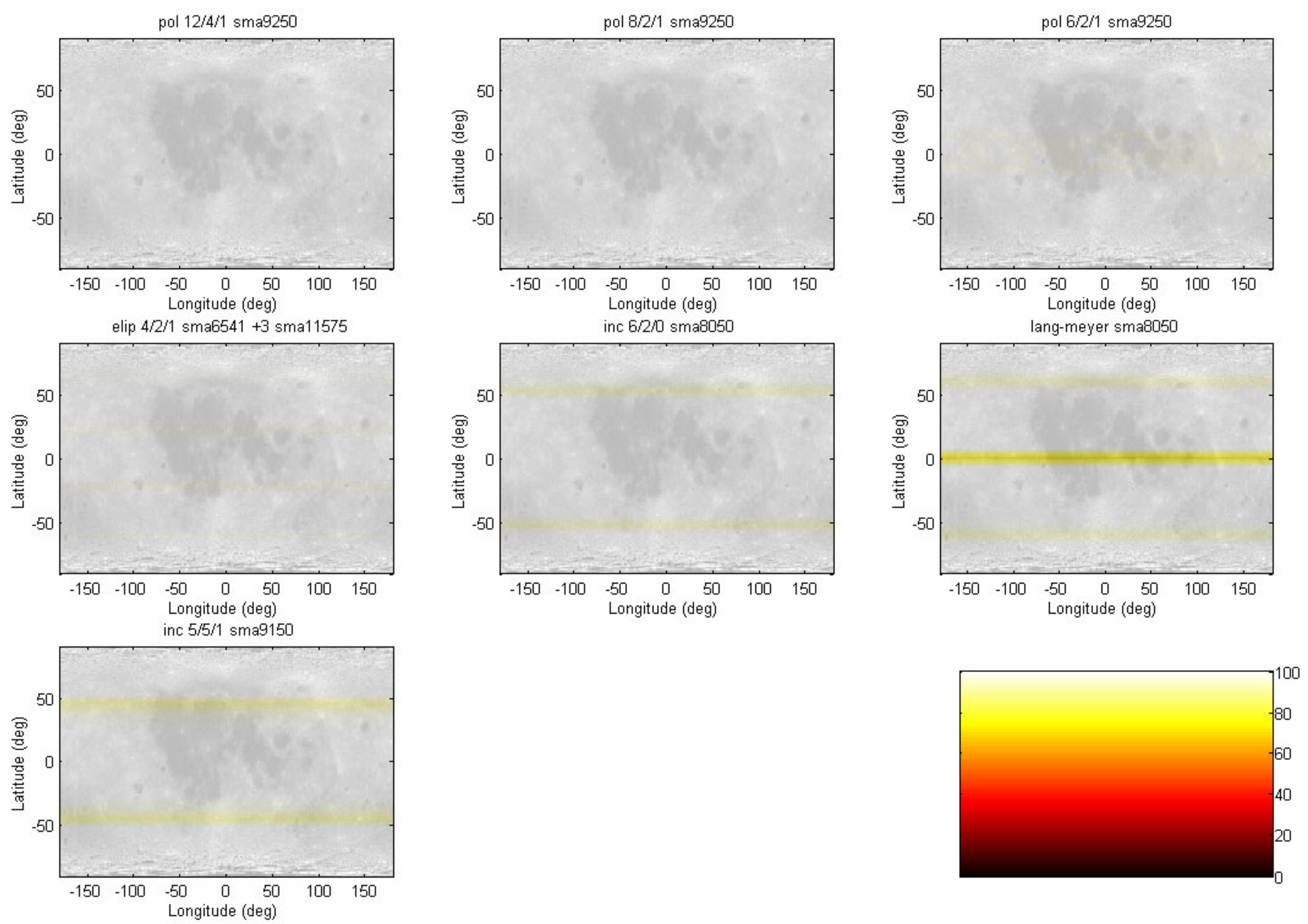

Figure B.2.17.1.—Lunar system availability results.

TABLE B.2.17.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.58	100.00	99.45	99.59	99.27
Pol 6/2/1 SMA 9250	99.37	100.00	99.17	99.37	98.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.45	100.00	99.45	99.44	99.25
Inc 6/2/0 SMA 8050	99.38	100.00	99.94	99.38	100.00
Lang-Meyer SMA 8050	97.23	100.00	97.11	97.23	96.24
Inc 5/5/1 SMA 9150	98.41	100.00	97.89	98.41	99.63

TABLE B.2.17.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.93	0.00	1.24	0.93	1.63
Pol 6/2/1 SMA 9250	2.91	0.56	3.79	2.90	5.04
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.05	4.74	0.55	1.04	0.48
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.04	0.00	0.54	1.04	0.49
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.53	0.00	4.64	3.53	4.76
Inc 6/2/0 SMA 8050	3.55	0.00	3.75	3.59	3.08
Lang-Meyer SMA 8050 - v1	4.57	0.00	6.00	4.53	7.44
Lang-Meyer SMA 8050 - v2	4.38	13.16	2.63	4.40	1.72
Inc 5/5/1 SMA 9150	7.69	6.22	6.84	7.69	5.81

B.2.18 Good terrain, two-way dynamic (1 hr).—Figure B.2.18.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with 1-hr dynamic measurements). Table B.2.18.1 tabulates the weighted system availabilities from figure B.2.18.1. Table B.2.18.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

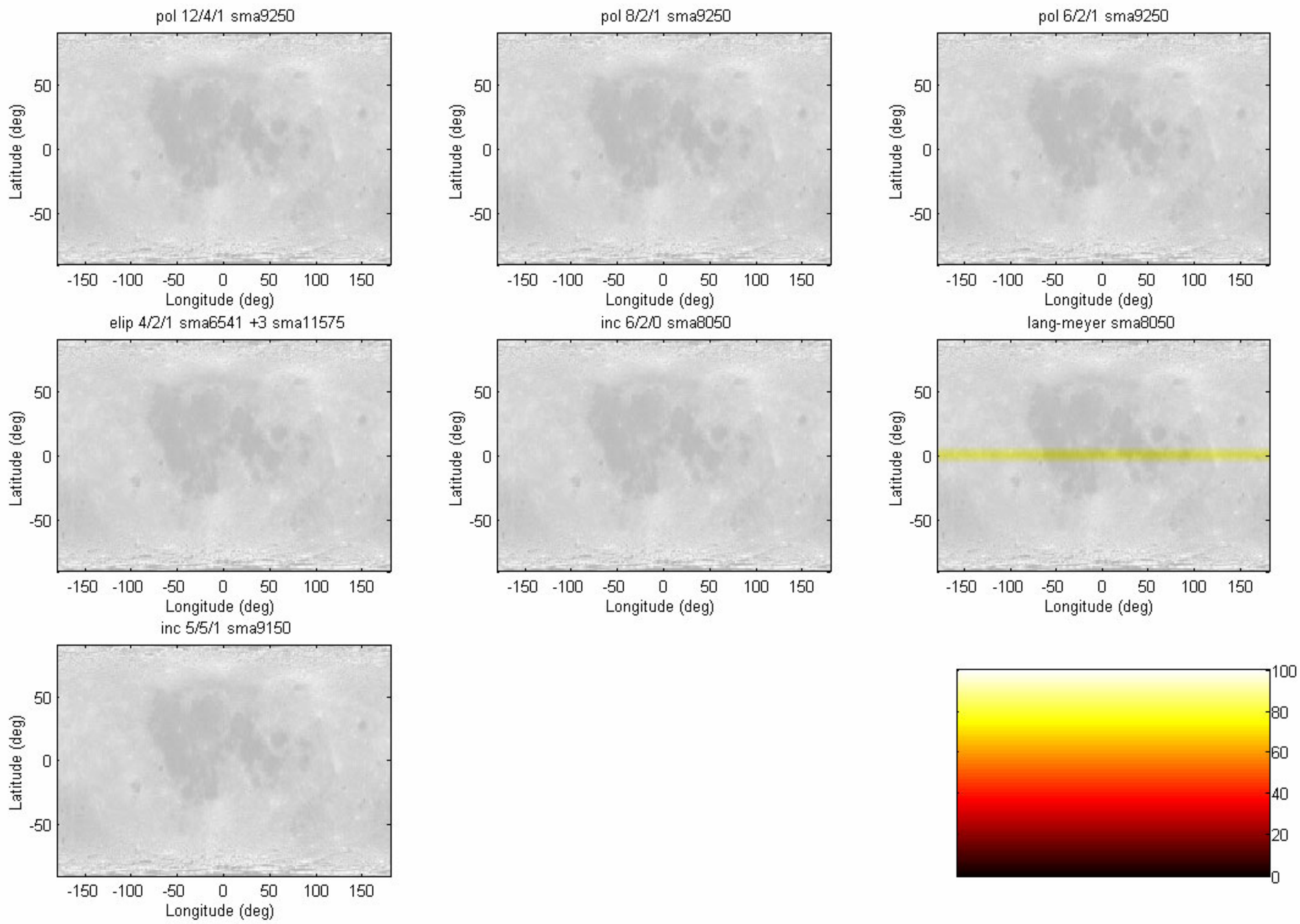

Figure B.2.18.1.—Lunar system availability results.

TABLE B.2.18.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.96	100.00	99.95	99.96	99.93
Pol 6/2/1 SMA 9250	99.95	100.00	99.93	99.95	99.92
Elip 4/2/1 SMA 6541 + 3 SMA 11575	100.00	100.00	100.00	100.00	100.00
Inc 6/2/0 SMA 8050	100.00	100.00	100.00	100.00	100.00
Lang-Meyer SMA 8050	98.43	100.00	97.92	98.43	97.19
Inc 5/5/1 SMA 9150	99.98	100.00	99.98	99.98	99.98

TABLE B.2.18.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.53	0.00	0.71	0.52	0.97
Pol 6/2/1 SMA 9250	2.11	0.00	2.81	2.10	3.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.26	1.25	0.11	0.25	0.03
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.25	0.00	0.10	0.25	0.02
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.50	0.00	3.31	2.50	3.32
Inc 6/2/0 SMA 8050	2.47	0.00	2.57	2.50	2.01
Lang-Meyer SMA 8050 - v1	2.45	0.00	3.27	2.42	4.37
Lang-Meyer SMA 8050 - v2	3.03	9.05	1.58	3.05	0.93
Inc 5/5/1 SMA 9150	5.99	3.31	5.36	5.99	3.95

B.3 User Minimum Elevation Angle of 15°

B.3.1 No terrain, no clock, one-way kinematic.—Figure B.3.1.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with kinematic measurements). Table B.3.1.1 tabulates the weighted system availabilities from figure B.3.1.1. Table B.3.1.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

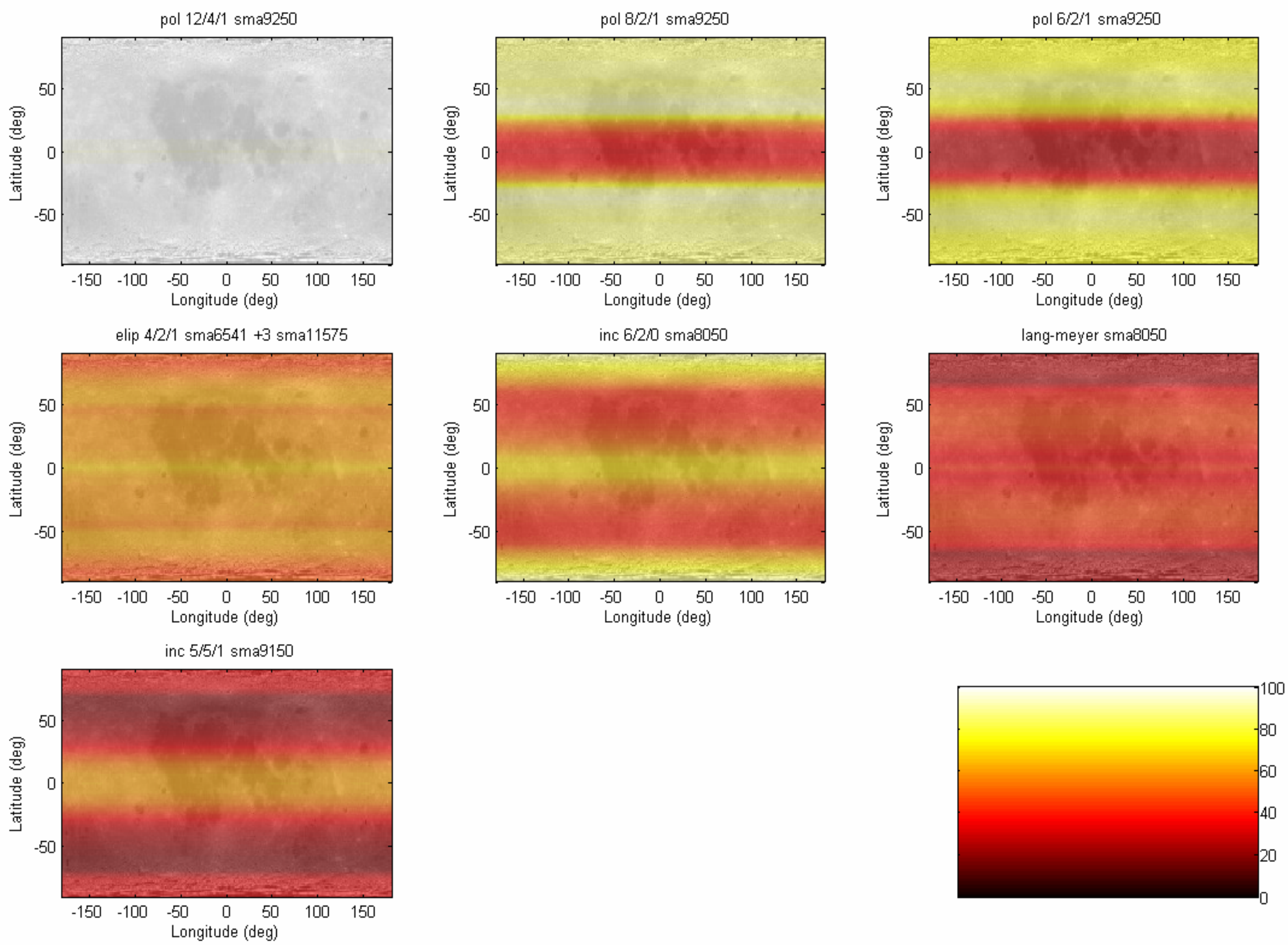

Figure B.3.1.1.—Lunar system availability results.

TABLE B.3.1.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.39	100.00	99.19	99.38	98.91
Pol 8/2/1 SMA 9250	68.10	84.79	62.28	68.10	52.67
Pol 6/2/1 SMA 9250	57.18	75.86	49.42	57.18	39.03
Elip 4/2/1 SMA 6541 + 3 SMA 11575	59.11	44.91	59.43	59.07	60.47
Inc 6/2/0 SMA 8050	52.75	79.64	53.17	52.76	57.33
Lang-Meyer SMA 8050	39.70	26.16	41.71	39.70	40.49
Inc 5/5/1 SMA 9150	38.24	32.51	43.67	38.27	50.17

TABLE B.3.1.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	2.83	0.00	3.73	2.81	4.76
Pol 8/2/1 SMA 9250	13.03	13.44	12.59	13.00	11.09
Pol 6/2/1 SMA 9250	18.64	22.40	16.27	18.61	12.93
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	12.73	14.59	12.81	12.71	13.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	12.73	1.85	12.75	12.76	12.99
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	17.22	13.05	17.18	17.13	17.49
Inc 6/2/0 SMA 8050	17.35	26.23	17.41	17.42	18.66
Lang-Meyer SMA 8050 - v1	16.39	0.00	19.19	16.27	18.63
Lang-Meyer SMA 8050 - v2	8.98	12.91	8.20	9.01	7.43
Inc 5/5/1 SMA 9150	15.26	12.98	17.38	15.30	19.99

***B.3.2 No terrain, no clock, one-way dynamic (15 min)*.**—Figure B.3.2.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with 15-min dynamic measurements). Table B.3.2.1 tabulates the weighted system availabilities from figure B.3.2.1. Table B.3.2.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

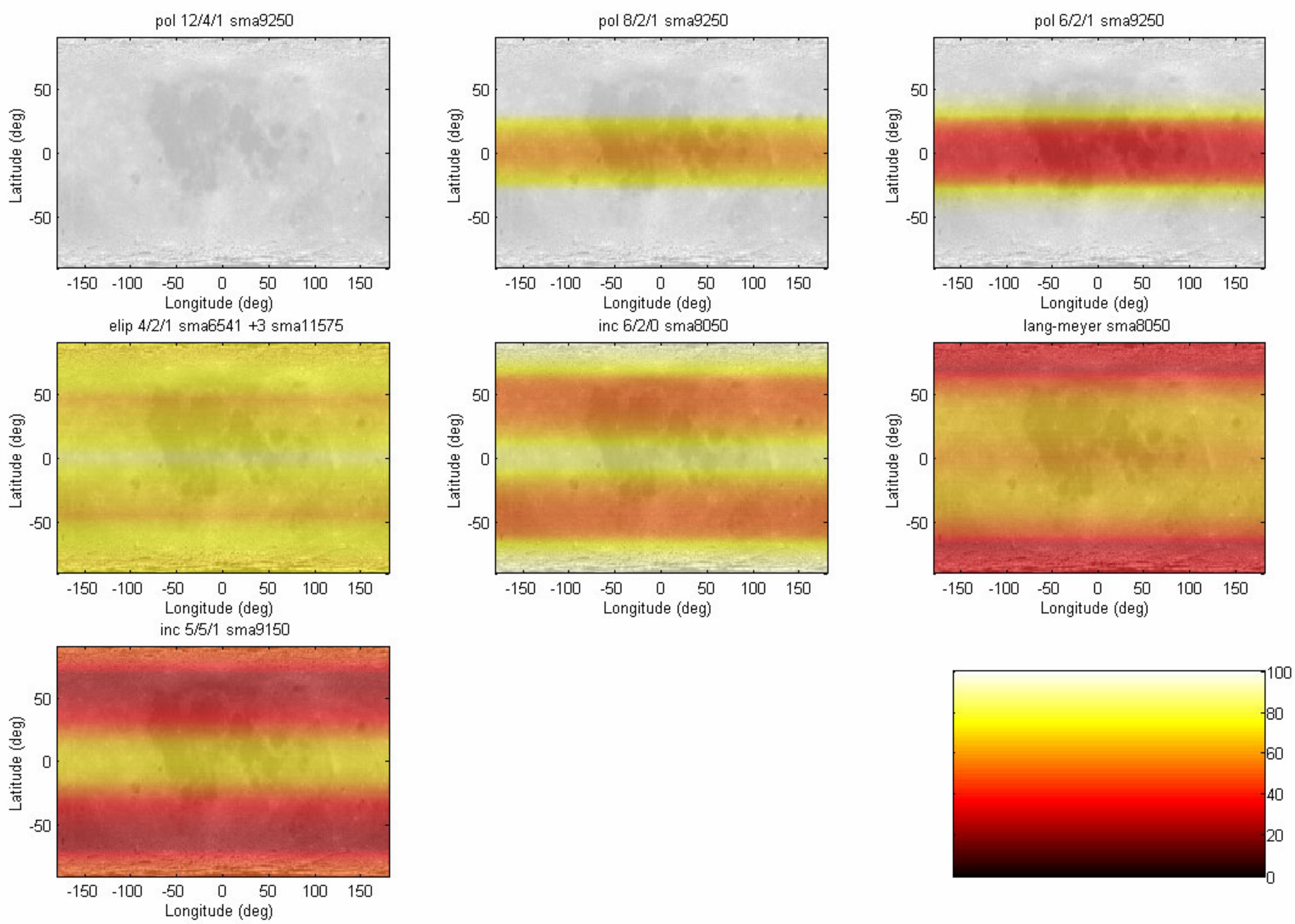

Figure B.3.2.1.—Lunar system availability results.

TABLE B.3.2.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.95	100.00	99.93	99.95	99.90
Pol 8/2/1 SMA 9250	84.47	100.00	79.38	84.46	72.09
Pol 6/2/1 SMA 9250	69.99	100.00	60.20	69.99	48.64
Elip 4/2/1 SMA 6541 + 3 SMA 11575	72.08	69.07	71.92	72.08	74.14
Inc 6/2/0 SMA 8050	64.35	90.06	64.53	64.34	69.36
Lang-Meyer SMA 8050	58.42	33.85	63.89	58.40	64.09
Inc 5/5/1 SMA 9150	46.82	46.80	52.36	46.85	59.28

TABLE B.3.2.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	1.99	0.00	2.67	1.97	3.61
Pol 8/2/1 SMA 9250	12.63	12.60	12.75	12.59	12.55
Pol 6/2/1 SMA 9250	21.89	29.19	19.09	21.86	15.50
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	14.32	30.98	13.90	14.29	14.64
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	14.32	2.83	13.83	14.35	14.49
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	15.65	8.57	16.12	15.59	16.65
Inc 6/2/0 SMA 8050	20.41	29.11	20.32	20.48	21.69
Lang-Meyer SMA 8050 - v1	14.10	0.00	15.81	14.00	13.52
Lang-Meyer SMA 8050 - v2	15.30	16.17	15.87	15.36	15.65
Inc 5/5/1 SMA 9150	18.17	18.23	20.29	18.21	23.03

B.3.3 No terrain, no clock, one-way dynamic (1 hr).—Figure B.3.3.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information or clock synchronization (solving with 1-hr dynamic measurements). Table B.3.3.1 tabulates the weighted system availabilities from figure B.3.3.1. Table B.3.3.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

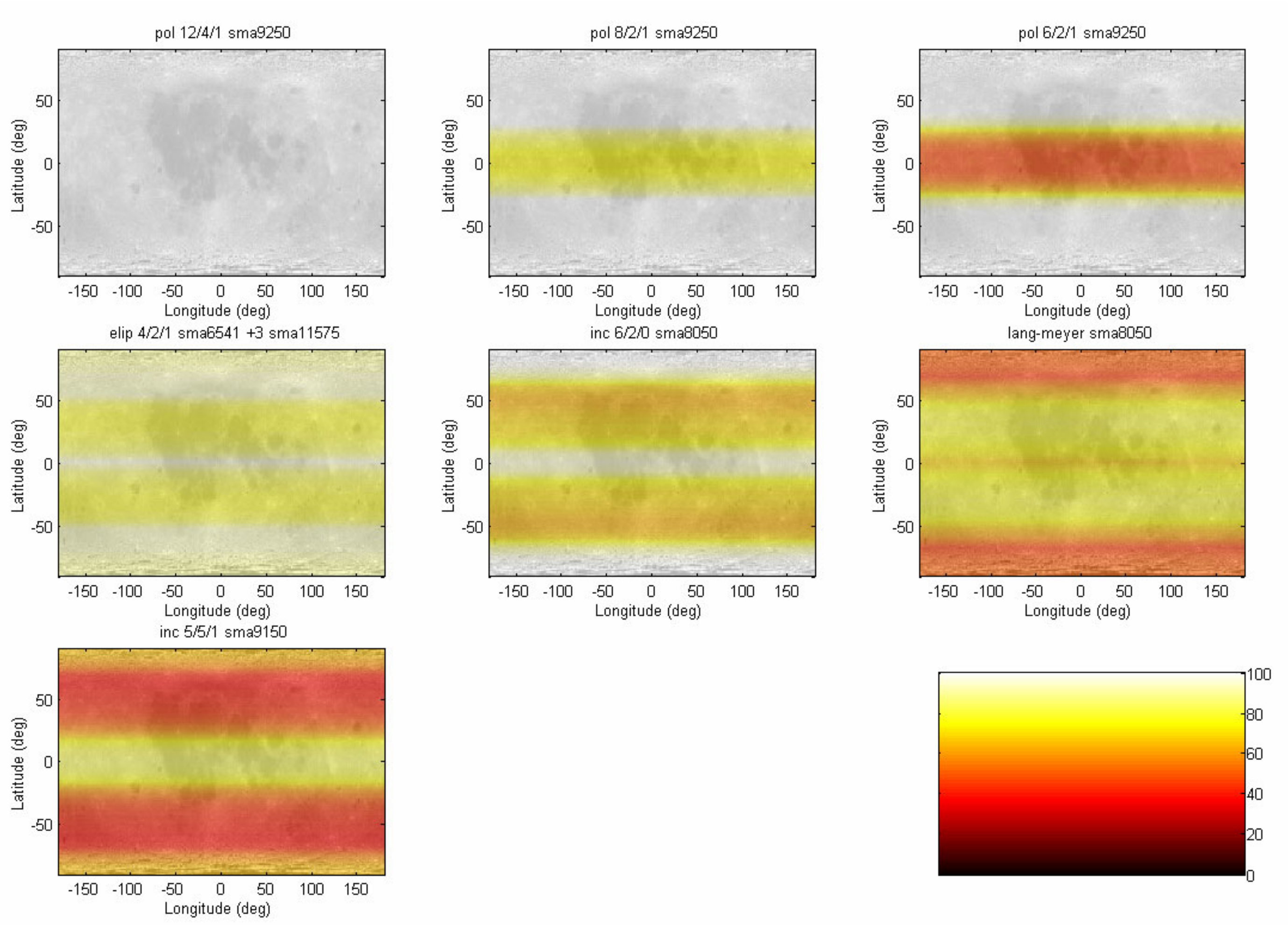

Figure B.3.3.1.—Lunar system availability results.

TABLE B.3.3.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	90.57	100.00	87.48	90.57	83.08
Pol 6/2/1 SMA 9250	77.88	100.00	70.64	77.88	60.61
Elip 4/2/1 SMA 6541 + 3 SMA 11575	84.97	89.30	82.55	84.96	83.36
Inc 6/2/0 SMA 8050	75.63	100.00	75.18	75.63	78.63
Lang-Meyer SMA 8050	71.25	50.51	76.29	71.23	75.79
Inc 5/5/1 SMA 9150	57.78	63.96	62.53	57.79	69.51

TABLE B.3.3.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	1.06	0.00	1.44	1.04	1.96
Pol 8/2/1 SMA 9250	8.63	0.02	9.93	8.62	11.17
Pol 6/2/1 SMA 9250	20.34	19.05	19.87	20.31	17.59
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	13.82	28.71	12.09	13.79	12.05
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	13.81	5.45	12.05	13.81	11.92
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	10.29	4.28	10.62	10.27	11.16
Inc 6/2/0 SMA 8050	19.93	28.42	19.59	20.01	20.17
Lang-Meyer SMA 8050 - v1	16.41	0.00	18.67	16.31	16.04
Lang-Meyer SMA 8050 - v2	16.23	24.44	15.86	16.29	14.96
Inc 5/5/1 SMA 9150	21.09	25.12	22.52	21.10	25.12

***B.3.4 Good terrain, no clock, one-way kinematic*.**—Figure B.3.4.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with kinematic measurements). Table B.3.4.1 tabulates the weighted system availabilities from figure B.3.4.1. Table B.3.4.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

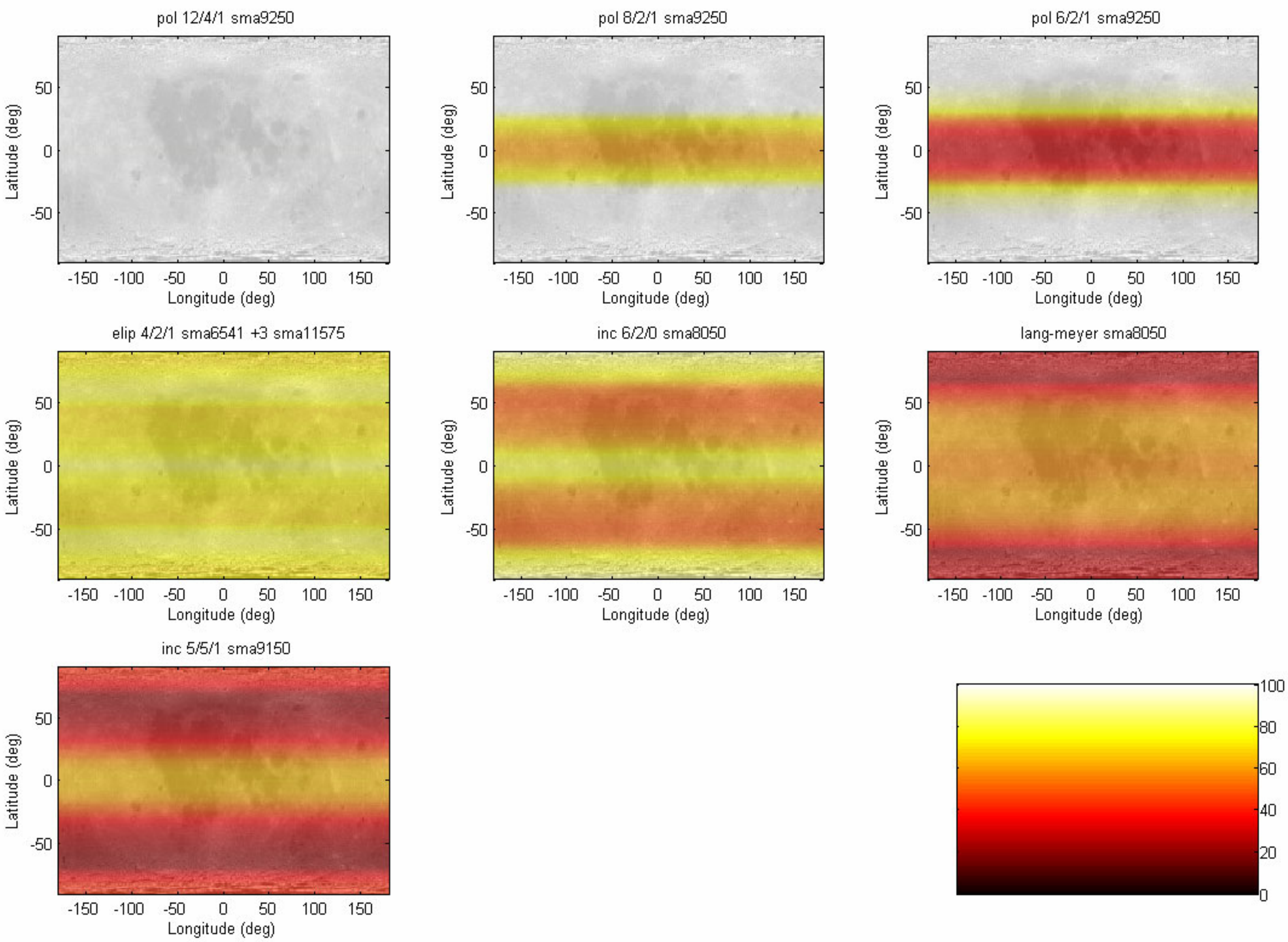

Figure B.3.4.1.—Lunar system availability results.

TABLE B.3.4.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.89	100.00	99.85	99.87	99.80
Pol 8/2/1 SMA 9250	84.95	100.00	80.03	84.95	72.96
Pol 6/2/1 SMA 9250	67.53	100.00	57.13	67.53	45.47
Elip 4/2/1 SMA 6541 + 3 SMA 11575	74.50	70.17	73.33	74.49	74.46
Inc 6/2/0 SMA 8050	62.16	82.88	62.59	62.16	66.52
Lang-Meyer SMA 8050	53.48	28.29	59.28	53.45	59.85
Inc 5/5/1 SMA 9150	42.37	41.08	47.97	42.40	54.73

TABLE B.3.4.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	2.40	0.00	3.20	2.36	4.34
Pol 8/2/1 SMA 9250	11.76	3.93	12.61	11.75	12.90
Pol 6/2/1 SMA 9250	21.35	27.89	18.58	21.32	14.93
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	15.68	37.80	14.17	15.64	14.06
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	15.68	1.84	14.09	15.69	13.87
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	17.65	7.97	18.89	17.57	20.04
Inc 6/2/0 SMA 8050	20.12	27.30	20.10	20.20	21.18
Lang-Meyer SMA 8050 - v1	13.28	0.00	15.01	13.17	12.88
Lang-Meyer SMA 8050 - v2	14.84	13.96	15.77	14.90	15.81
Inc 5/5/1 SMA 9150	16.91	16.39	19.10	16.96	21.81

B.3.5 Good terrain, no clock, one-way dynamic (15 min).—Figure B.3.5.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with 15-min dynamic measurements). Table B.3.5.1 tabulates the weighted system availabilities from figure B.3.5.1. Table B.3.5.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

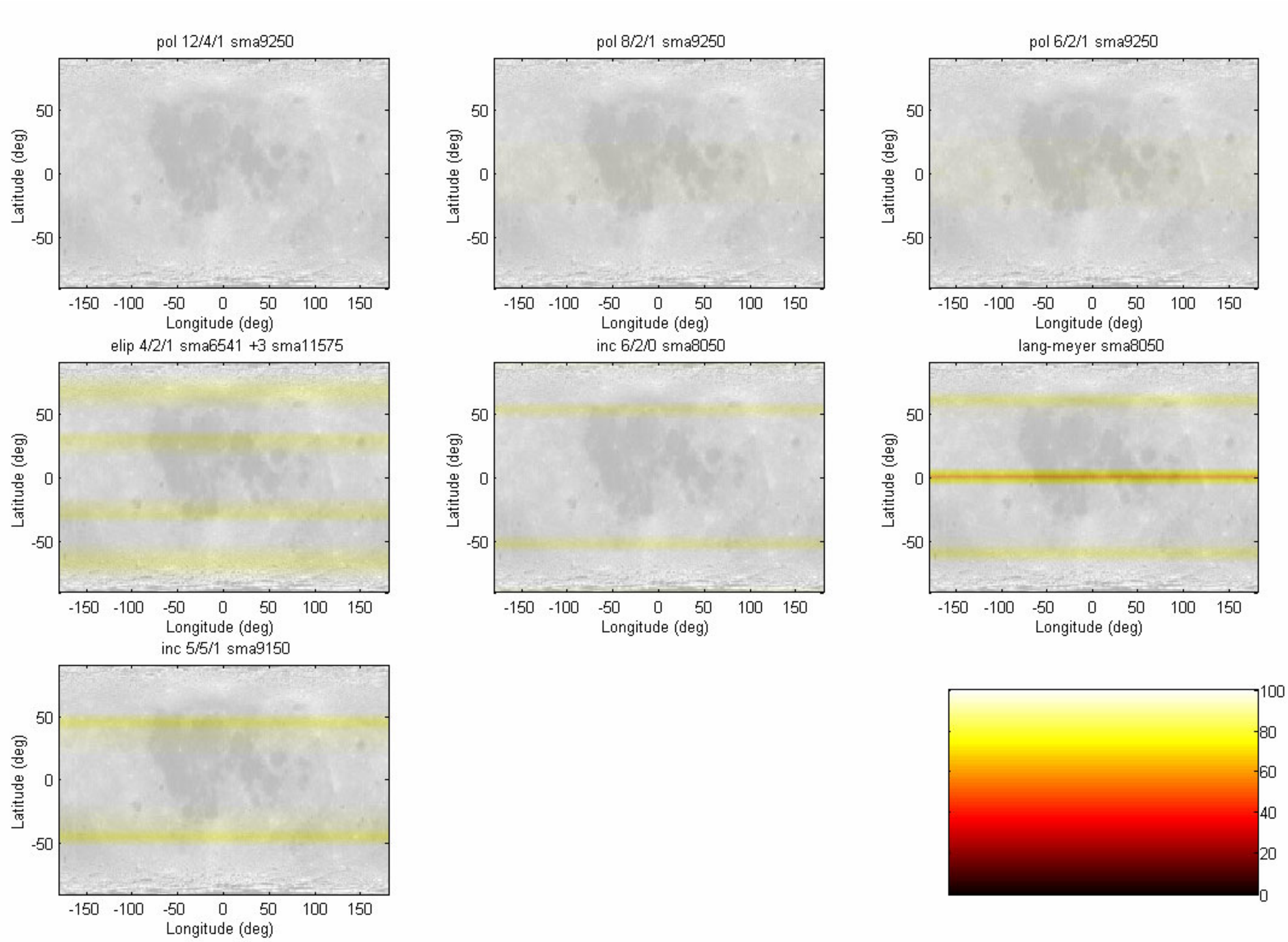

Figure B.3.5.1.—Lunar system availability results.

TABLE B.3.5.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.99	100.00	99.98	99.99	99.97
Pol 8/2/1 SMA 9250	99.22	100.00	98.96	99.22	98.58
Pol 6/2/1 SMA 9250	98.64	100.00	98.20	98.65	97.71
Elip 4/2/1 SMA 6541 + 3 SMA 11575	96.20	100.00	96.80	96.21	95.76
Inc 6/2/0 SMA 8050	98.83	99.94	99.60	98.83	99.76
Lang-Meyer SMA 8050	96.07	100.00	96.25	96.06	95.20
Inc 5/5/1 SMA 9150	96.93	100.00	96.03	96.93	98.58

TABLE B.3.5.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.04	0.00	0.05	0.05	0.07
Pol 8/2/1 SMA 9250	1.94	0.33	2.49	1.92	3.28
Pol 6/2/1 SMA 9250	5.25	2.99	6.66	5.22	8.42
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.10	13.36	1.33	2.10	1.12
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.11	0.00	1.32	2.12	1.13
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	5.53	0.00	7.00	5.52	6.76
Inc 6/2/0 SMA 8050	5.95	2.08	6.07	6.00	5.45
Lang-Meyer SMA 8050 - v1	7.06	0.00	9.17	7.00	10.73
Lang-Meyer SMA 8050 - v2	6.53	16.84	4.16	6.56	3.06
Inc 5/5/1 SMA 9150	10.68	11.03	9.50	10.69	8.72

B.3.6 Good terrain, no clock, one-way dynamic (1 hr).—Figure B.3.6.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information but without clock synchronization (solving with 1-hr dynamic measurements). Table B.3.6.1 tabulates the weighted system availabilities from figure B.3.6.1. Table B.3.6.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

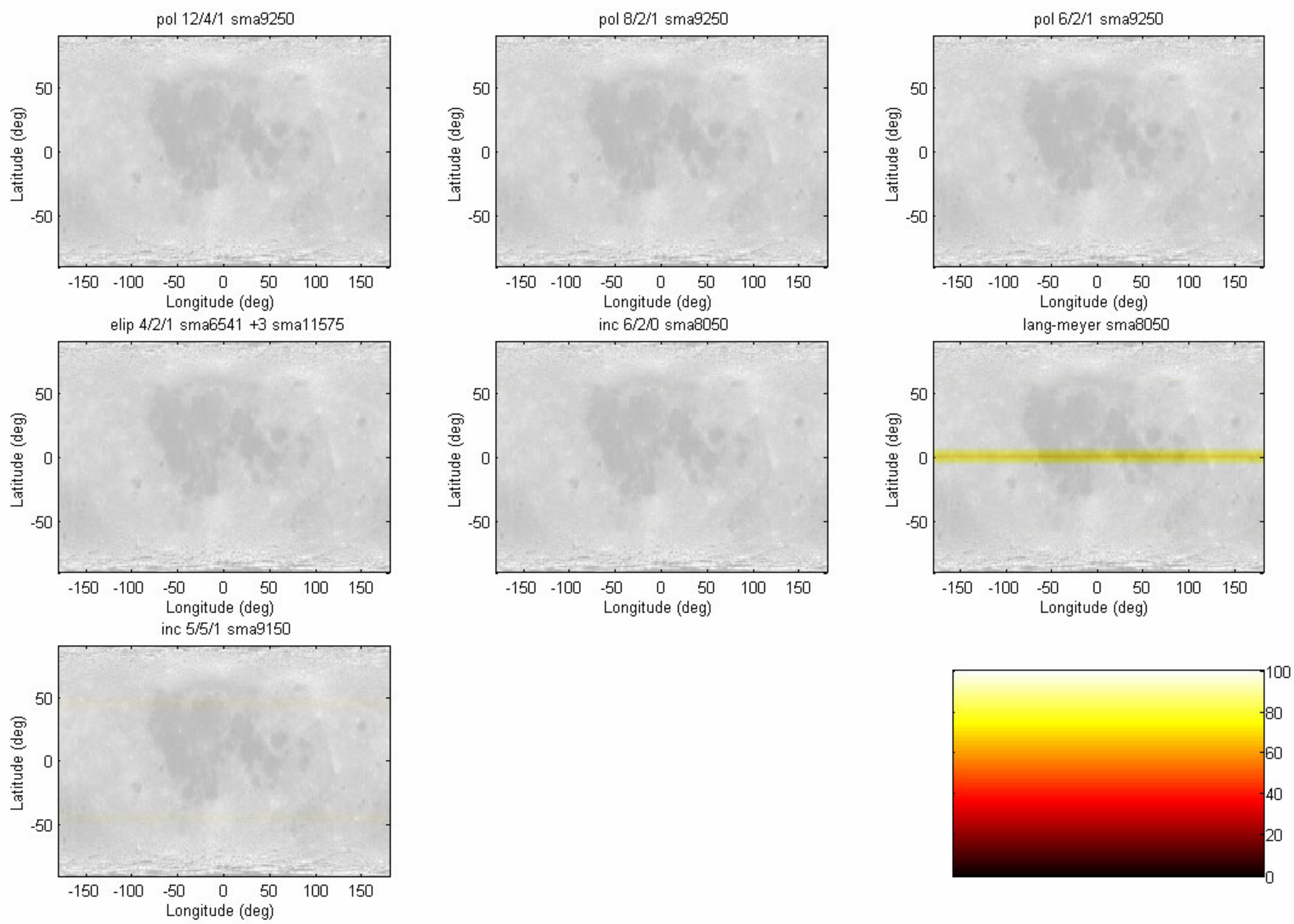

Figure B.3.6.1.—Lunar system availability results.

TABLE B.3.6.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.92	100.00	99.89	99.92	99.87
Pol 6/2/1 SMA 9250	99.83	100.00	99.78	99.83	99.70
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.80	100.00	99.89	99.80	99.85
Inc 6/2/0 SMA 8050	99.86	100.00	99.98	99.86	100.00
Lang-Meyer SMA 8050	97.73	100.00	97.15	97.73	96.18
Inc 5/5/1 SMA 9150	99.53	100.00	99.39	99.53	99.86

TABLE B.3.6.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.24	0.00	1.65	1.23	2.24
Pol 6/2/1 SMA 9250	3.84	0.34	5.09	3.81	6.78
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.84	6.19	0.39	0.83	0.17
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.83	0.00	0.38	0.84	0.14
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	4.16	0.00	5.43	4.13	5.33
Inc 6/2/0 SMA 8050	4.22	0.00	4.26	4.27	3.67
Lang-Meyer SMA 8050 - v1	4.27	0.00	5.68	4.24	7.24
Lang-Meyer SMA 8050 - v2	4.87	12.74	2.75	4.90	1.87
Inc 5/5/1 SMA 9150	8.72	7.60	7.77	8.72	6.43

B.3.7 No terrain, 3-hr clock synchronization, one-way kinematic.—Figure B.3.7.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with kinematic measurements). Table B.3.7.1 tabulates the weighted system availabilities from figure B.3.7.1. Table B.3.7.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

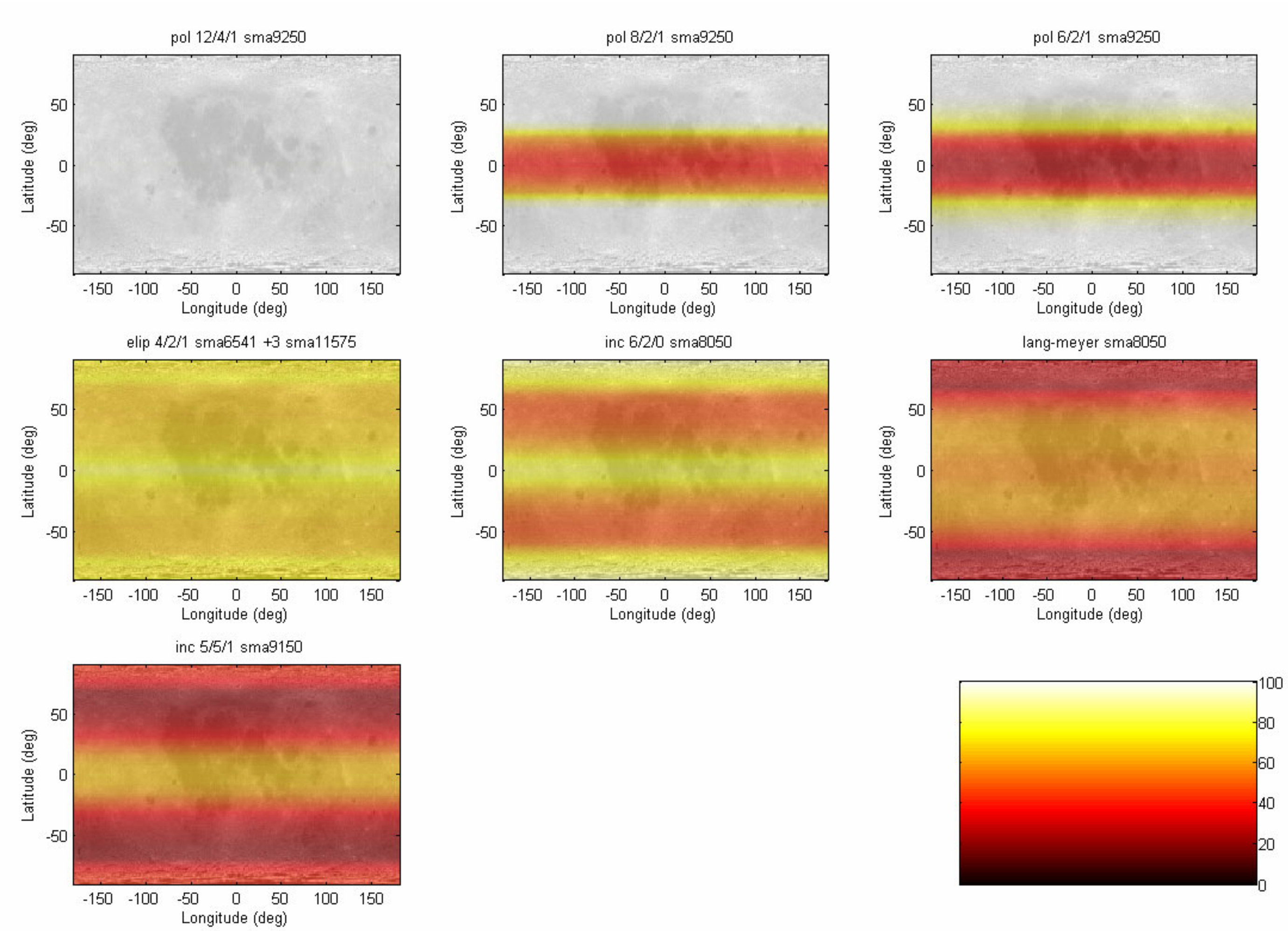

Figure B.3.7.1.—Lunar system availability results.

TABLE B.3.7.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.89	100.00	99.85	99.89	99.80
Pol 8/2/1 SMA 9250	75.83	100.00	67.92	75.84	56.73
Pol 6/2/1 SMA 9250	65.65	99.92	54.65	65.66	42.66
Elip 4/2/1 SMA 6541 + 3 SMA 11575	69.71	70.17	70.31	69.72	71.64
Inc 6/2/0 SMA 8050	61.11	82.88	61.57	61.11	66.17
Lang-Meyer SMA 8050	53.46	28.30	59.28	53.41	59.84
Inc 5/5/1 SMA 9150	42.36	41.06	47.97	42.40	54.73

TABLE B.3.7.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	2.42	0.00	3.22	2.39	4.36
Pol 8/2/1 SMA 9250	11.50	13.93	10.80	11.48	9.51
Pol 6/2/1 SMA 9250	21.20	30.28	17.93	21.17	14.09
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	14.78	37.80	14.60	14.76	14.84
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	14.80	1.98	14.57	14.83	14.72
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	17.29	7.97	18.26	17.22	19.05
Inc 6/2/0 SMA 8050	20.02	27.30	20.05	20.10	21.40
Lang-Meyer SMA 8050 - v1	13.36	0.01	15.15	13.21	13.10
Lang-Meyer SMA 8050 - v2	14.82	13.97	15.77	14.86	15.81
Inc 5/5/1 SMA 9150	16.96	16.39	19.13	17.01	21.84

B.3.8 No terrain, 3-hr clock synchronization, one-way dynamic (15 min).—Figure B.3.8.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with 15-min dynamic measurements). Table B.3.8.1 tabulates the weighted system availabilities from figure B.3.8.1. Table B.3.8.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

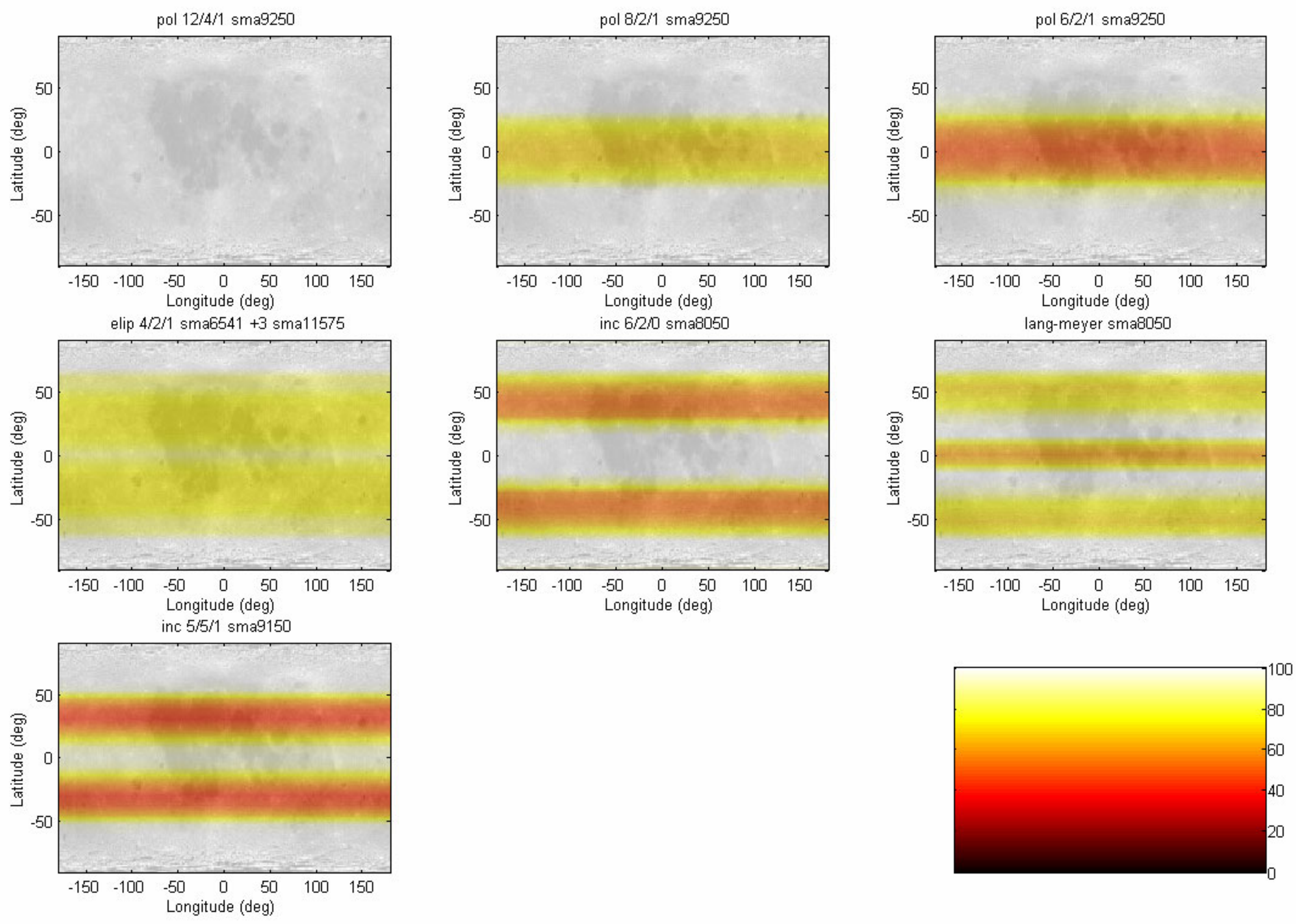

Figure B.3.8.1.—Lunar system availability results.

TABLE B.3.8.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.95	100.00	99.93	99.95	99.90
Pol 8/2/1 SMA 9250	87.44	100.00	83.33	87.45	77.63
Pol 6/2/1 SMA 9250	78.52	100.00	71.52	78.51	62.74
Elip 4/2/1 SMA 6541 + 3 SMA 11575	79.09	100.00	75.16	79.08	75.53
Inc 6/2/0 SMA 8050	79.23	99.94	78.70	79.16	87.91
Lang-Meyer SMA 8050	82.66	99.78	82.47	82.66	85.40
Inc 5/5/1 SMA 9150	73.47	99.96	65.28	73.50	69.20

TABLE B.3.8.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.68	0.00	0.91	0.68	1.23
Pol 8/2/1 SMA 9250	3.96	5.68	3.67	3.88	3.57
Pol 6/2/1 SMA 9250	8.04	19.78	5.54	8.05	4.11
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	9.72	13.48	10.70	9.70	12.64
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	9.73	0.10	10.68	9.72	12.47
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	2.92	0.00	3.65	2.87	3.42
Inc 6/2/0 SMA 8050	7.19	2.06	8.44	7.31	9.89
Lang-Meyer SMA 8050 - v1	9.15	0.00	11.35	9.04	10.53
Lang-Meyer SMA 8050 - v2	7.13	16.81	5.72	7.20	6.69
Inc 5/5/1 SMA 9150	11.70	11.02	10.38	11.80	11.67

B.3.9 No terrain, 3-hr clock synchronization, one-way dynamic (1 hr).—Figure B.3.9.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode without terrain information but with 3-hr clock synchronization (solving with 1-hr dynamic measurements). Table B.3.9.1 tabulates the weighted system availabilities from figure B.3.9.1. Table B.3.9.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

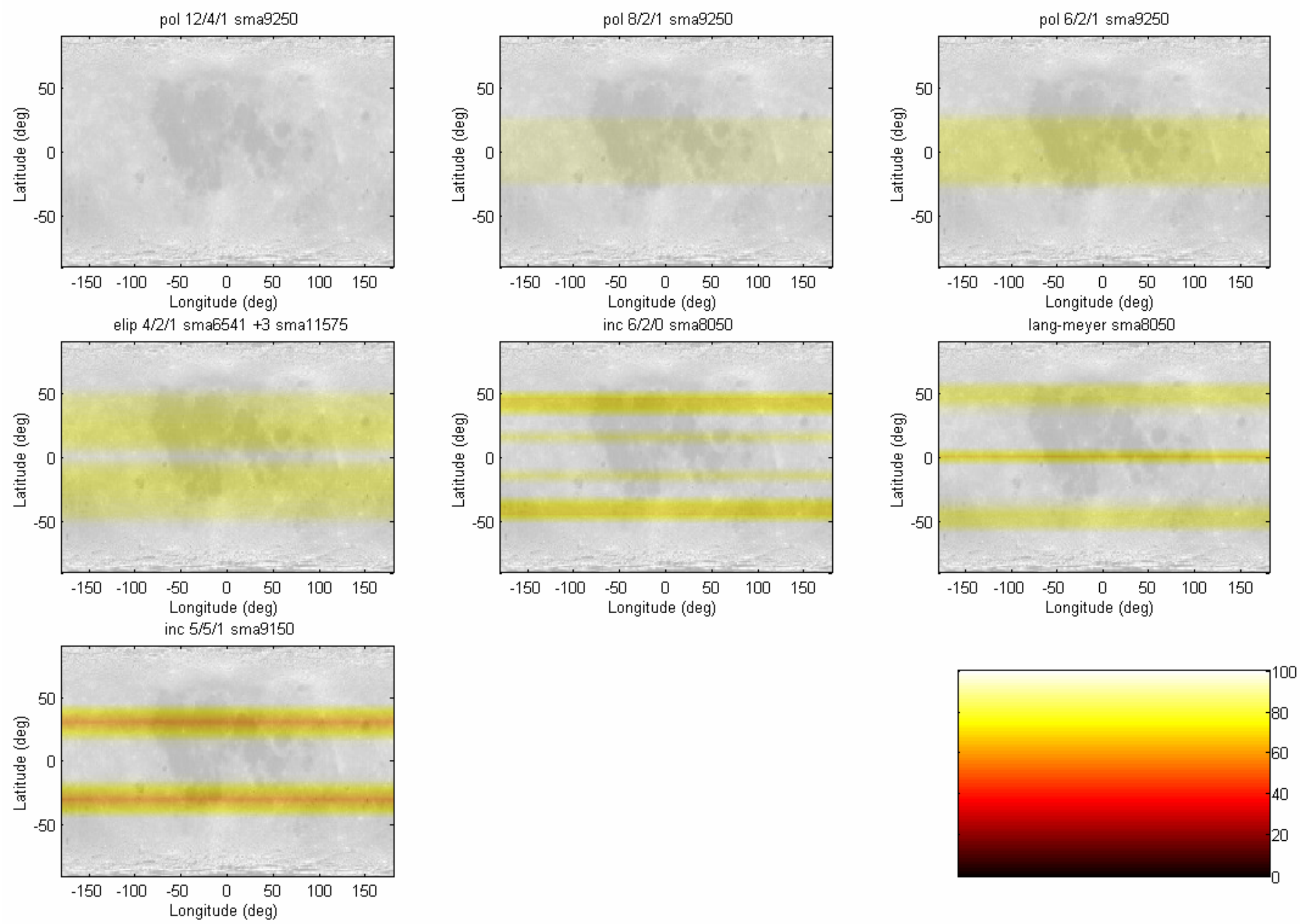

Figure B.3.9.1.—Lunar system availability results.

TABLE B.3.9.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	96.92	100.00	95.92	96.92	94.49
Pol 6/2/1 SMA 9250	93.45	100.00	91.30	93.46	88.30
Elip 4/2/1 SMA 6541 + 3 SMA 11575	89.05	100.00	85.75	89.04	85.34
Inc 6/2/0 SMA 8050	92.28	100.00	89.82	92.29	96.41
Lang-Meyer SMA 8050	93.85	99.90	93.69	93.87	95.87
Inc 5/5/1 SMA 9150	88.61	100.00	84.93	88.65	84.74

TABLE B.3.9.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.02	0.00	0.02	0.02	0.03
Pol 8/2/1 SMA 9250	2.63	0.00	3.11	2.63	3.83
Pol 6/2/1 SMA 9250	6.11	3.46	6.23	6.16	7.14
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	3.82	6.25	3.56	3.80	4.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	3.82	0.05	3.56	3.79	3.98
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	1.27	0.00	1.72	1.16	2.16
Inc 6/2/0 SMA 8050	5.51	0.01	5.41	5.69	5.42
Lang-Meyer SMA 8050 - v1	7.53	0.00	9.56	7.45	9.94
Lang-Meyer SMA 8050 - v2	5.03	12.71	3.18	5.09	3.24
Inc 5/5/1 SMA 9150	10.23	7.60	9.40	10.32	8.72

__B.3.10 Good terrain, 3-hr clock synchronization, one-way kinematic__.—Figure B.3.10.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with kinematic measurements). Table B.3.10.1 tabulates the weighted system availabilities from figure B.3.10.1. Table B.3.10.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

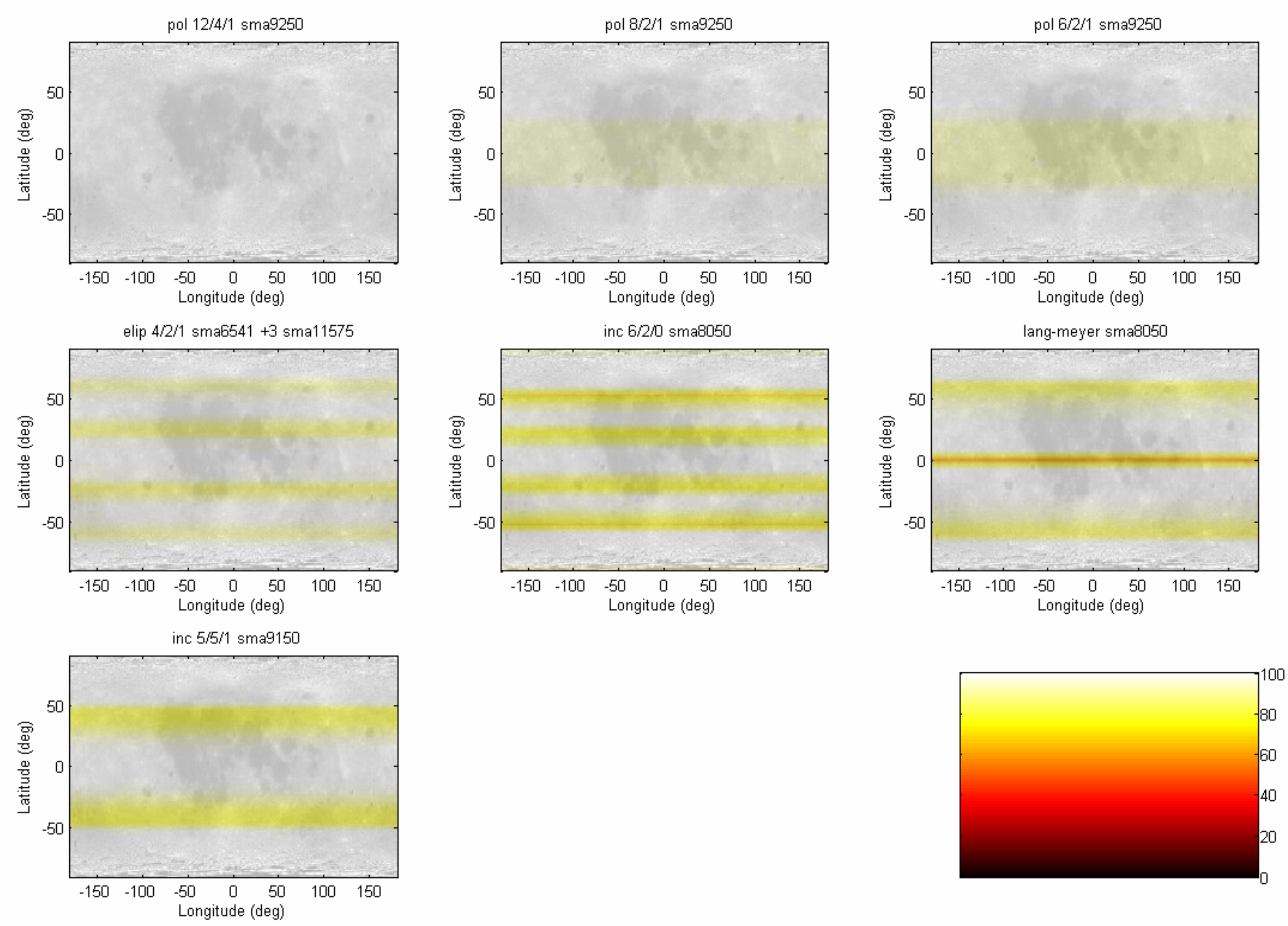

Figure B.3.10.1.—Lunar system availability results.

TABLE B.3.10.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.94	100.00	99.93	99.94	99.90
Pol 8/2/1 SMA 9250	97.21	100.00	96.31	97.20	94.92
Pol 6/2/1 SMA 9250	95.56	100.00	94.17	95.56	92.62
Elip 4/2/1 SMA 6541 + 3 SMA 11575	94.93	100.00	94.90	94.89	93.31
Inc 6/2/0 SMA 8050	90.60	98.98	90.87	90.62	90.51
Lang-Meyer SMA 8050	93.57	99.75	94.74	93.62	94.57
Inc 5/5/1 SMA 9150	92.87	99.94	90.69	92.96	95.16

TABLE B.3.10.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.14	0.00	0.18	0.15	0.23
Pol 8/2/1 SMA 9250	2.50	1.58	2.89	2.53	3.64
Pol 6/2/1 SMA 9250	8.17	9.35	9.58	8.32	11.74
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.70	15.10	1.74	2.68	1.48
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.70	0.12	1.70	2.69	1.42
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	8.75	0.00	11.40	8.66	10.77
Inc 6/2/0 SMA 8050	7.49	2.66	7.92	7.68	6.69
Lang-Meyer SMA 8050 - v1	8.47	0.00	10.82	8.34	12.13
Lang-Meyer SMA 8050 - v2	7.02	17.73	4.86	7.14	3.97
Inc 5/5/1 SMA 9150	13.93	11.77	12.18	14.17	11.44

B.3.11 Good terrain, 3-hr clock synchronization, one-way dynamic (15 min).—Figure B.3.11.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with 15-min dynamic measurements). Table B.3.11.1 tabulates the weighted system availabilities from figure B.3.11.1. Table B.3.11.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

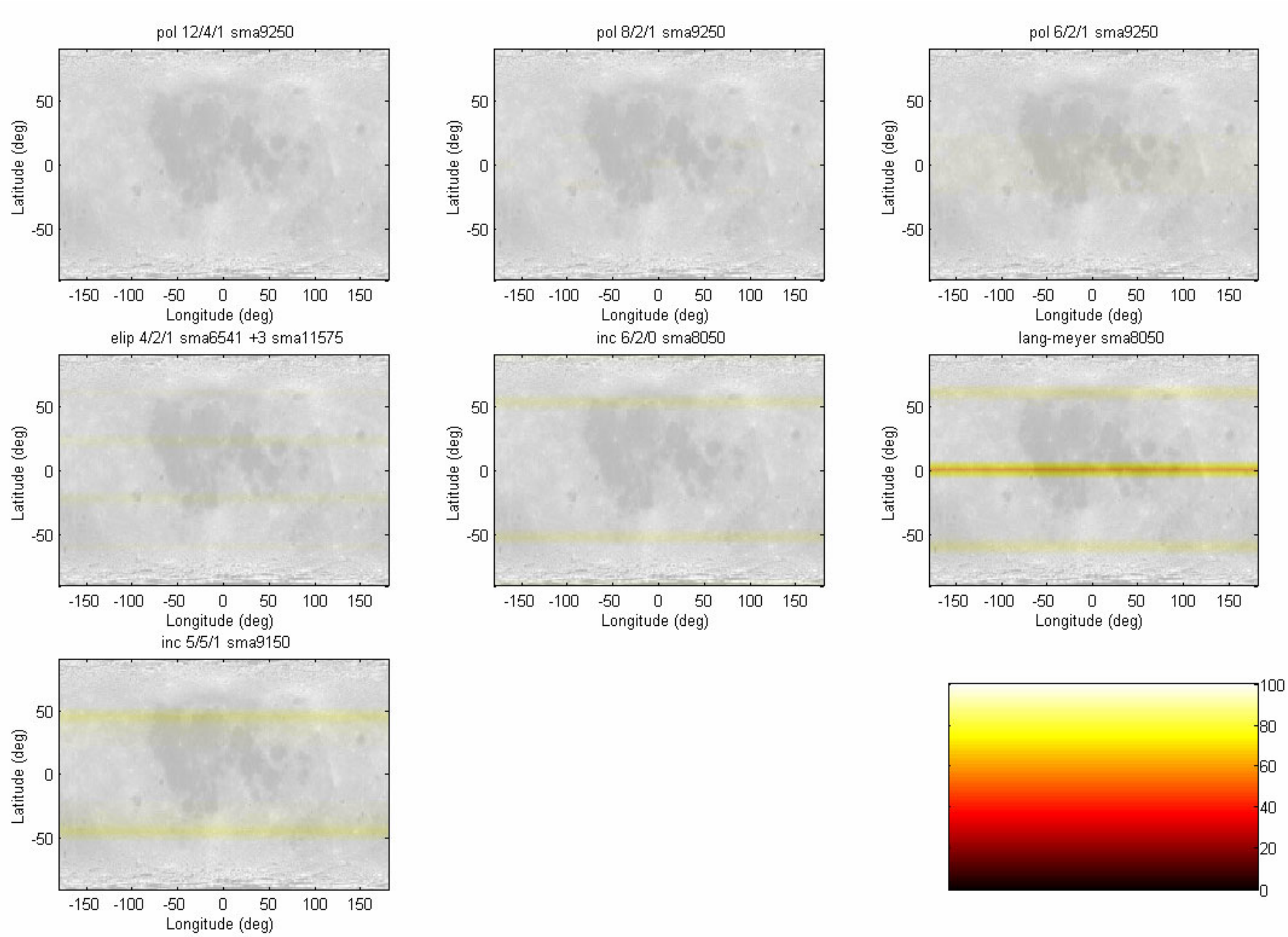

Figure B.3.11.1.—Lunar system availability results.

TABLE B.3.11.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.99	100.00	99.98	99.99	99.98
Pol 8/2/1 SMA 9250	99.39	100.00	99.18	99.39	98.95
Pol 6/2/1 SMA 9250	99.16	100.00	98.89	99.16	98.50
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.08	100.00	99.04	99.07	98.72
Inc 6/2/0 SMA 8050	99.19	100.00	99.74	99.19	99.84
Lang-Meyer SMA 8050	96.45	100.00	96.31	96.45	95.21
Inc 5/5/1 SMA 9150	97.85	100.00	97.24	97.86	98.98

TABLE B.3.11.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.03	0.00	0.02	0.03	0.04
Pol 8/2/1 SMA 9250	1.75	0.04	2.29	1.73	3.09
Pol 6/2/1 SMA 9250	4.90	0.68	6.44	4.87	8.26
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.78	12.49	0.95	1.78	0.63
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.78	0.00	0.95	1.78	0.65
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	5.55	0.00	7.20	5.54	7.47
Inc 6/2/0 SMA 8050	5.73	1.64	5.80	5.78	5.19
Lang-Meyer SMA 8050 - v1	6.63	0.00	8.69	6.58	10.28
Lang-Meyer SMA 8050 - v2	6.38	16.36	4.00	6.42	2.89
Inc 5/5/1 SMA 9150	10.50	10.63	9.35	10.52	8.39

B.3.12 Good terrain, 3-hr clock synchronization, one-way dynamic (1 hr).—Figure B.3.12.1 shows the system availability results for the seven lunar constellations when the system is operating in one-way mode with terrain information and with 3-hr clock synchronization (solving with 1-hr dynamic measurements). Table B.3.12.1 tabulates the weighted system availabilities from figure B.3.12.1. Table B.3.12.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

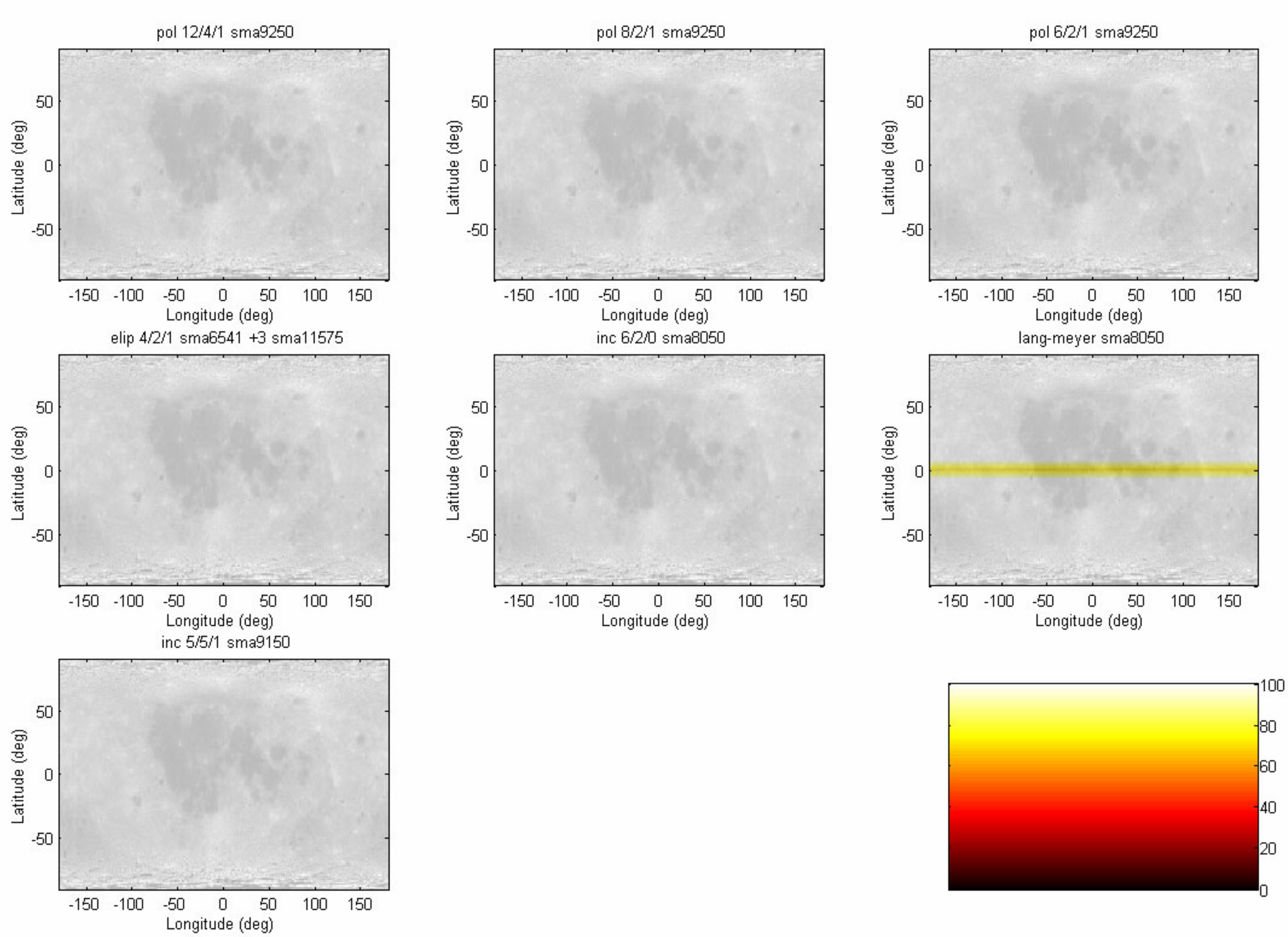

Figure B.3.12.1.—Lunar system availability results.

TABLE B.3.12.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.95	100.00	99.93	99.95	99.91
Pol 6/2/1 SMA 9250	99.94	100.00	99.92	99.94	99.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.97	100.00	99.96	99.97	99.95
Inc 6/2/0 SMA 8050	100.00	100.00	100.00	100.00	100.00
Lang-Meyer SMA 8050	97.87	100.00	97.17	97.87	96.18
Inc 5/5/1 SMA 9150	99.96	100.00	99.95	99.96	99.96

TABLE B.3.12.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.14	0.00	1.53	1.13	2.09
Pol 6/2/1 SMA 9250	3.68	0.00	4.92	3.66	6.59
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.63	5.42	0.28	0.63	0.08
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.63	0.00	0.28	0.63	0.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	4.00	0.00	5.24	3.98	5.15
Inc 6/2/0 SMA 8050	4.09	0.00	4.10	4.13	3.52
Lang-Meyer SMA 8050 - v1	3.97	0.00	5.30	3.94	6.80
Lang-Meyer SMA 8050 - v2	4.72	12.26	2.62	4.75	1.76
Inc 5/5/1 SMA 9150	8.52	7.21	7.59	8.52	6.17

***B.3.13 No terrain, two-way kinematic*.**—Figure B.3.13.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with kinematic measurements). Table B.3.13.1 tabulates the weighted system availabilities from figure B.3.13.1. Table B.3.13.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

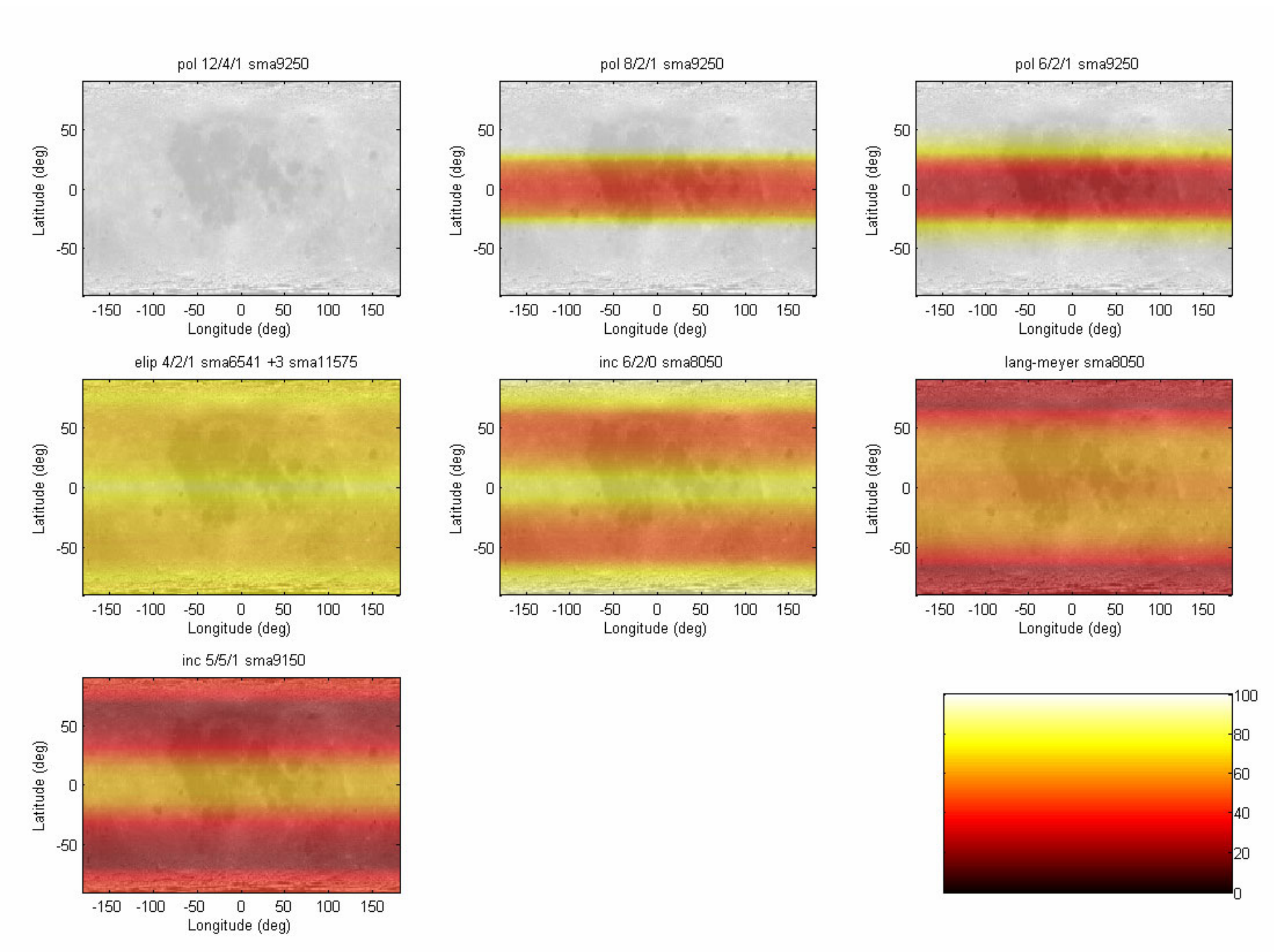

Figure B.3.13.1.—Lunar system availability results.

TABLE B.3.13.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.89	100.00	99.85	99.89	99.80
Pol 8/2/1 SMA 9250	76.44	100.00	68.73	76.44	57.75
Pol 6/2/1 SMA 9250	65.84	100.00	54.89	65.85	42.94
Elip 4/2/1 SMA 6541 + 3 SMA 11575	69.88	70.17	70.35	69.88	71.70
Inc 6/2/0 SMA 8050	61.16	82.88	61.62	61.16	66.21
Lang-Meyer SMA 8050	53.48	28.29	59.28	53.45	59.85
Inc 5/5/1 SMA 9150	42.37	41.08	47.97	42.40	54.73

TABLE B.3.13.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	2.41	0.00	3.22	2.39	4.36
Pol 8/2/1 SMA 9250	11.58	13.93	10.93	11.54	9.68
Pol 6/2/1 SMA 9250	21.23	30.28	17.97	21.20	14.12
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	14.84	37.80	14.61	14.81	14.87
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	14.84	1.84	14.54	14.87	14.71
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	17.28	7.97	18.26	17.21	19.05
Inc 6/2/0 SMA 8050	20.04	27.30	20.07	20.11	21.41
Lang-Meyer SMA 8050 - v1	13.28	0.00	15.00	13.17	12.88
Lang-Meyer SMA 8050 - v2	14.84	13.96	15.77	14.89	15.81
Inc 5/5/1 SMA 9150	16.91	16.39	19.10	16.96	21.81

B.3.14 No terrain, two-way dynamic (15 min).—Figure B.3.14.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with 15-min dynamic measurements). Table B.3.14.1 tabulates the weighted system availabilities from figure B.3.14.1. Table B.3.14.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

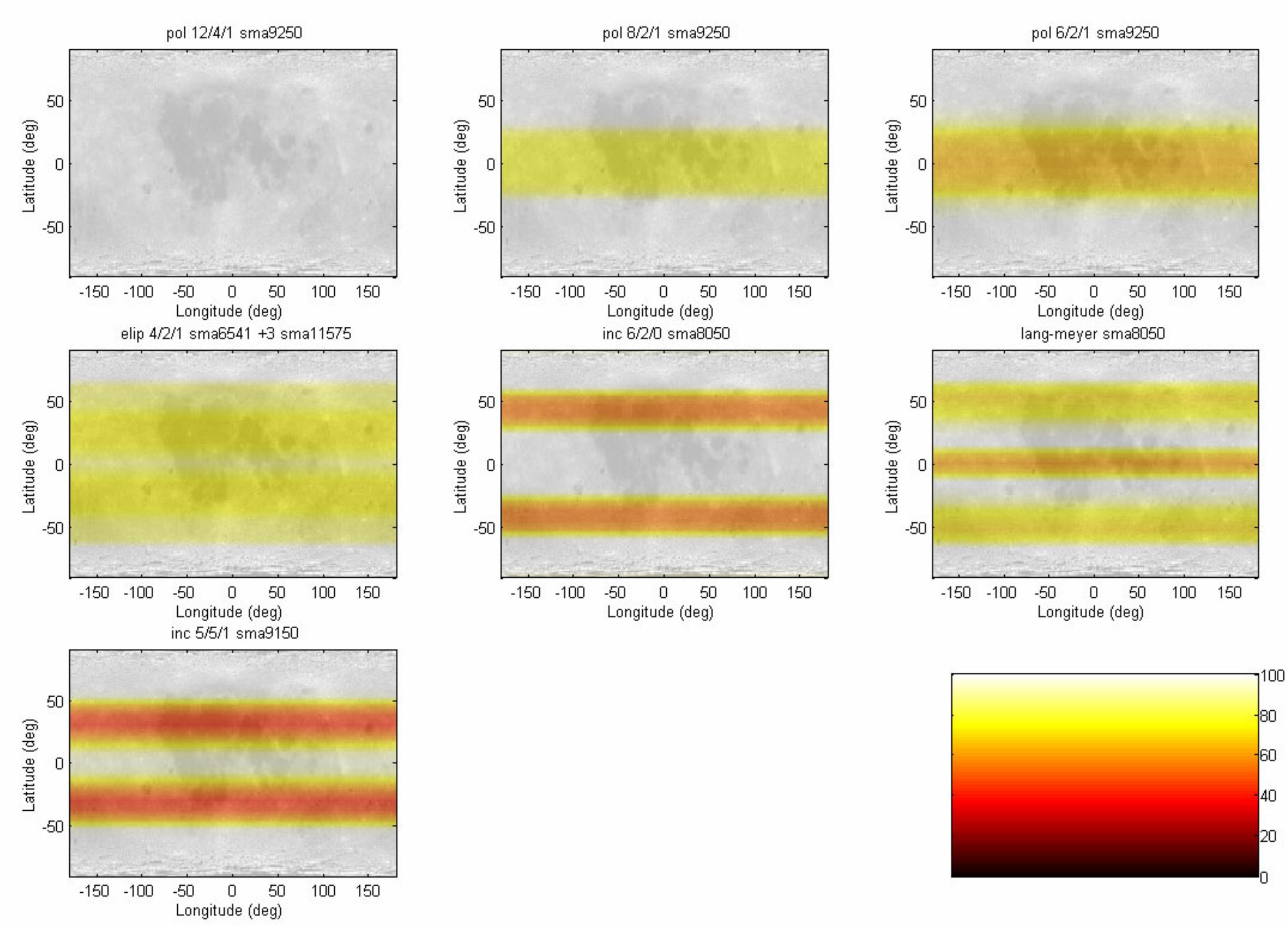

Figure B.3.14.1.—Lunar system availability results.

TABLE B.3.14.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.95	100.00	99.93	99.95	99.90
Pol 8/2/1 SMA 9250	90.06	100.00	86.80	90.06	82.15
Pol 6/2/1 SMA 9250	83.11	100.00	77.60	83.11	70.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575	80.02	100.00	76.39	80.01	75.75
Inc 6/2/0 SMA 8050	83.62	99.94	82.51	83.62	92.58
Lang-Meyer SMA 8050	82.71	100.00	82.52	82.69	85.52
Inc 5/5/1 SMA 9150	73.49	100.00	65.25	73.51	69.14

TABLE B.3.14.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.68	0.00	0.91	0.67	1.23
Pol 8/2/1 SMA 9250	4.51	5.68	4.33	4.47	4.60
Pol 6/2/1 SMA 9250	9.42	19.78	7.46	9.35	6.63
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	9.70	13.62	10.68	9.65	12.65
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	9.71	0.00	10.63	9.71	12.49
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.56	0.00	4.46	3.54	3.56
Inc 6/2/0 SMA 8050	8.38	2.06	9.63	8.43	11.39
Lang-Meyer SMA 8050 - v1	9.26	0.00	11.48	9.19	10.57
Lang-Meyer SMA 8050 - v2	7.14	16.82	5.78	7.17	6.77
Inc 5/5/1 SMA 9150	11.57	11.03	10.47	11.59	11.90

B.3.15 No terrain, two-way dynamic (1 hr).—Figure B.3.15.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode without terrain information (solving with 1-hr dynamic measurements). Table B.3.15.1 tabulates the weighted system availabilities from figure B.3.15.1. Table B.3.15.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

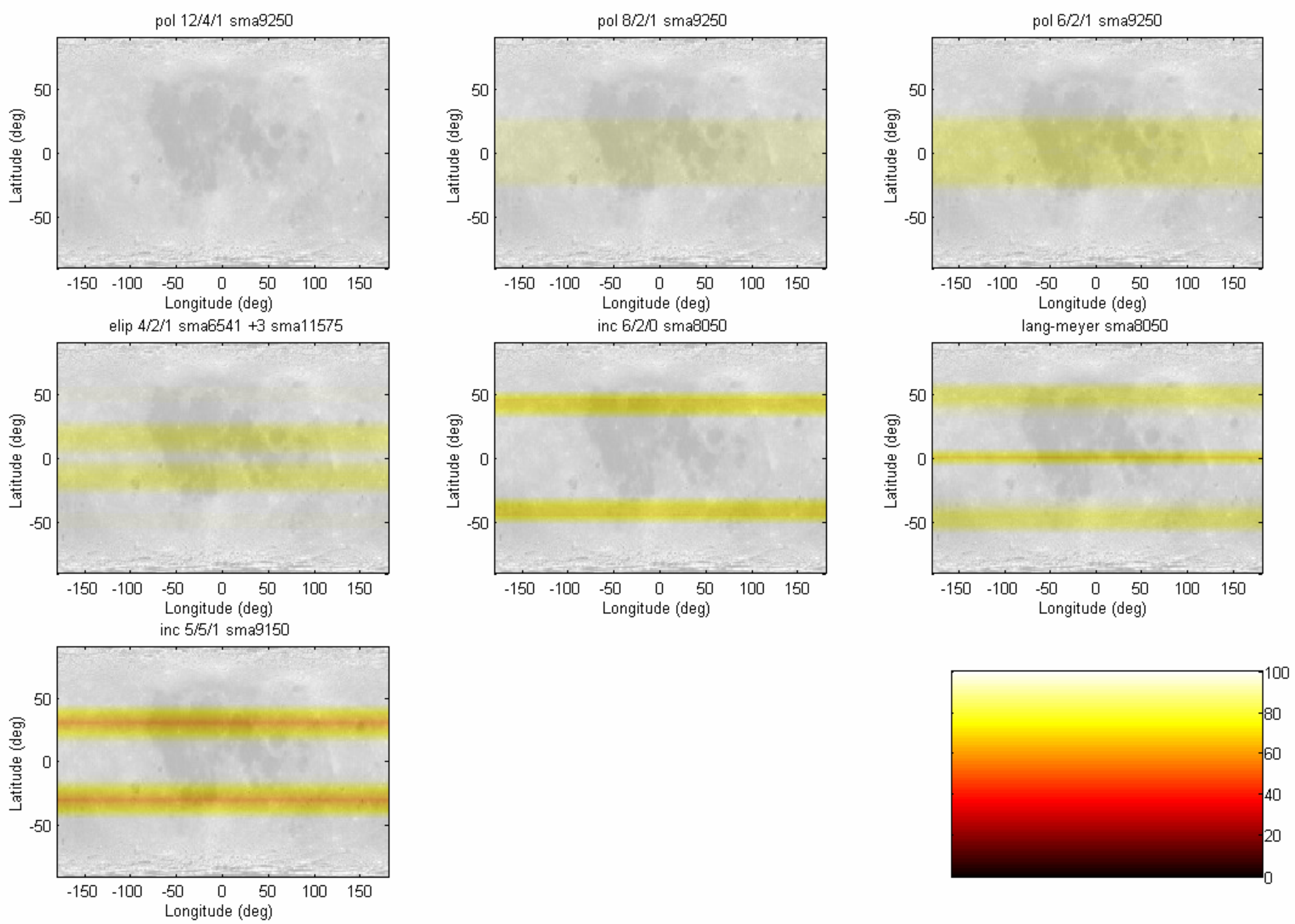

Figure B.3.15.1.—Lunar system availability results.

TABLE B.3.15.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	96.94	100.00	95.93	96.94	94.52
Pol 6/2/1 SMA 9250	93.53	100.00	91.41	93.53	88.43
Elip 4/2/1 SMA 6541 + 3 SMA 11575	93.87	100.00	92.13	93.86	89.72
Inc 6/2/0 SMA 8050	94.14	100.00	92.28	94.14	99.73
Lang-Meyer SMA 8050	93.89	100.00	93.73	93.88	95.93
Inc 5/5/1 SMA 9150	88.72	100.00	85.04	88.72	84.83

TABLE B.3.15.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.02	0.00	0.02	0.02	0.03
Pol 8/2/1 SMA 9250	2.66	0.00	3.15	2.64	3.91
Pol 6/2/1 SMA 9250	5.77	3.46	5.88	5.72	6.62
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	3.66	6.33	3.36	3.63	3.96
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	3.65	0.00	3.31	3.64	3.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.73	0.00	4.87	3.71	4.22
Inc 6/2/0 SMA 8050	5.78	0.01	6.11	5.82	6.43
Lang-Meyer SMA 8050 - v1	7.61	0.00	9.65	7.55	9.93
Lang-Meyer SMA 8050 - v2	5.01	12.71	3.22	5.04	3.30
Inc 5/5/1 SMA 9150	10.12	7.60	9.46	10.11	8.89

***B.3.16 Good terrain, two-way kinematic*.**—Figure B.3.16.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with kinematic measurements). Table B.3.16.1 tabulates the weighted system availabilities from figure B.3.16.1. Table B.3.16.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

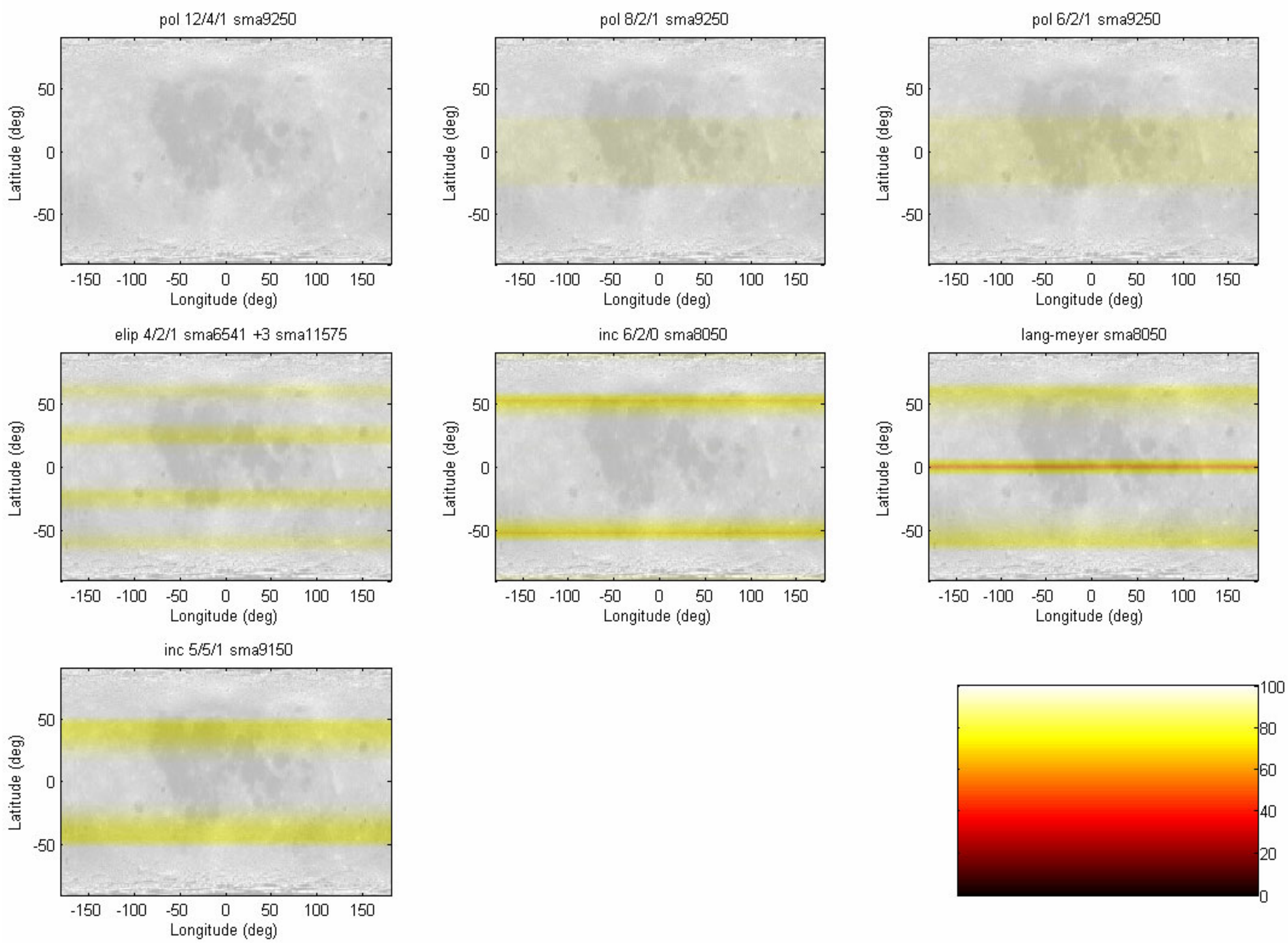

Figure B.3.16.1.—Lunar system availability results.

TABLE B.3.16.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.94	100.00	99.93	99.94	99.90
Pol 8/2/1 SMA 9250	97.25	100.00	96.35	97.24	95.02
Pol 6/2/1 SMA 9250	95.70	100.00	94.35	95.69	92.83
Elip 4/2/1 SMA 6541 + 3 SMA 11575	95.01	100.00	94.97	95.01	93.40
Inc 6/2/0 SMA 8050	95.62	98.98	97.53	95.62	99.38
Lang-Meyer SMA 8050	93.66	100.00	94.85	93.66	94.71
Inc 5/5/1 SMA 9150	93.10	100.00	90.99	93.11	95.48

TABLE B.3.16.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.13	0.00	0.18	0.13	0.23
Pol 8/2/1 SMA 9250	2.45	1.58	2.89	2.43	3.64
Pol 6/2/1 SMA 9250	6.00	9.35	6.87	5.98	8.31
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.65	15.10	1.67	2.64	1.44
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.65	0.00	1.65	2.66	1.42
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	5.76	0.00	7.38	5.73	7.02
Inc 6/2/0 SMA 8050	6.92	2.66	7.51	6.97	7.10
Lang-Meyer SMA 8050 - v1	8.27	0.00	10.57	8.21	11.91
Lang-Meyer SMA 8050 - v2	6.89	17.73	4.84	6.93	3.97
Inc 5/5/1 SMA 9150	11.04	11.77	9.79	11.05	9.66

***B.3.17 Good terrain, two-way dynamic (15 min)*.**—Figure B.3.17.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with 15-min dynamic measurements). Table B.3.17.1 tabulates the weighted system availabilities from figure B.3.17.1. Table B.3.17.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

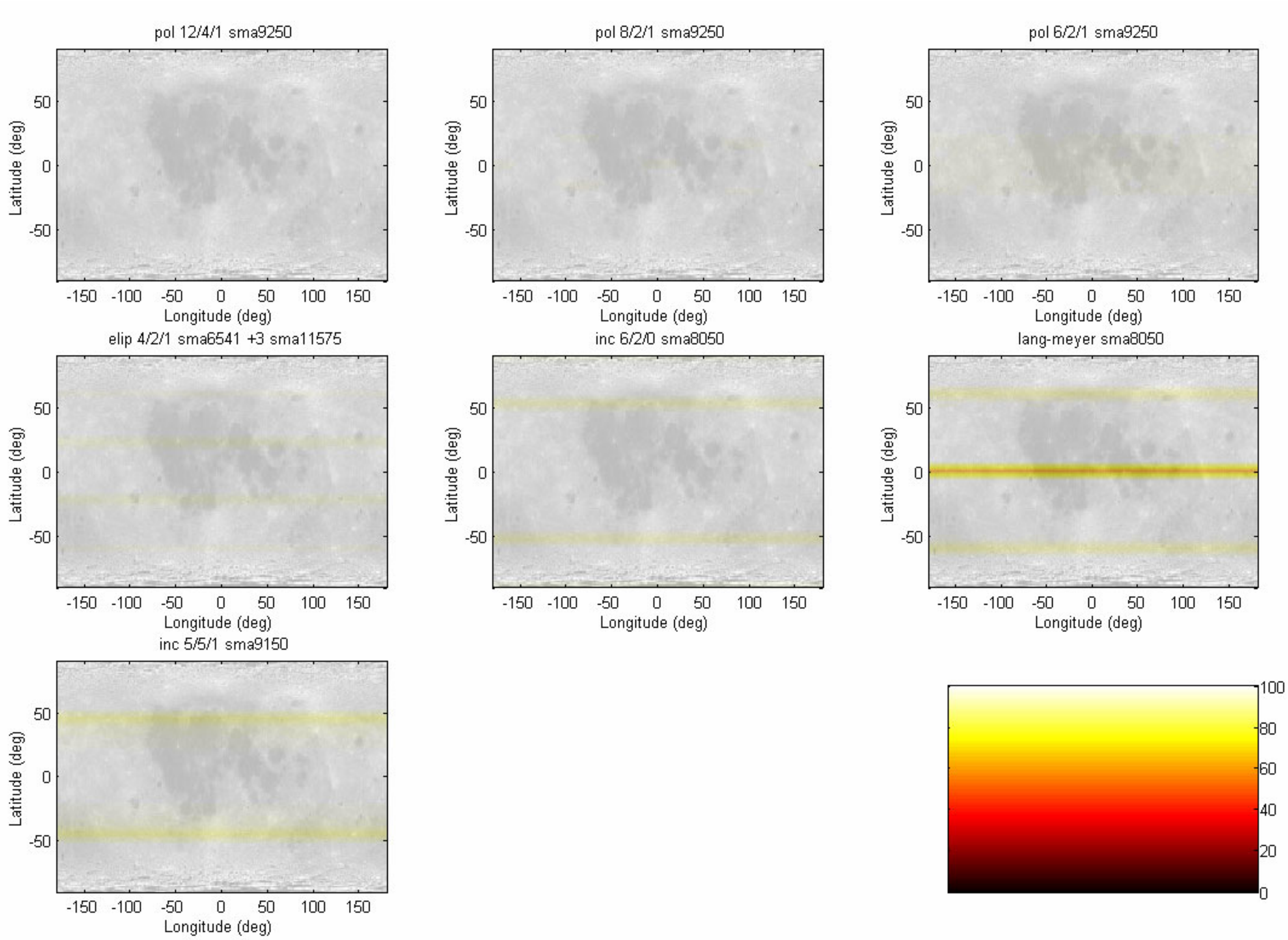

Figure B.3.17.1.—Lunar system availability results.

TABLE B.3.17.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	99.99	100.00	99.98	99.99	99.98
Pol 8/2/1 SMA 9250	99.39	100.00	99.18	99.39	98.95
Pol 6/2/1 SMA 9250	99.16	100.00	98.89	99.16	98.50
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.09	100.00	99.05	99.09	98.74
Inc 6/2/0 SMA 8050	99.19	100.00	99.74	99.19	99.84
Lang-Meyer SMA 8050	96.45	100.00	96.31	96.45	95.21
Inc 5/5/1 SMA 9150	97.86	100.00	97.25	97.86	98.98

TABLE B.3.17.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.03	0.00	0.02	0.03	0.04
Pol 8/2/1 SMA 9250	1.75	0.04	2.30	1.73	3.10
Pol 6/2/1 SMA 9250	4.91	0.68	6.44	4.88	8.27
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	1.78	12.49	0.95	1.78	0.63
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	1.78	0.00	0.94	1.79	0.65
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	5.42	0.00	7.01	5.42	7.13
Inc 6/2/0 SMA 8050	5.73	1.64	5.80	5.78	5.19
Lang-Meyer SMA 8050 - v1	6.64	0.00	8.70	6.59	10.28
Lang-Meyer SMA 8050 - v2	6.38	16.36	4.00	6.42	2.89
Inc 5/5/1 SMA 9150	10.52	10.63	9.37	10.53	8.39

B.3.18 Good terrain, two-way dynamic (1 hr).—Figure B.3.18.1 shows the system availability results for the seven lunar constellations when the system is operating in two-way mode with terrain information (solving with 1-hr dynamic measurements). Table B.3.18.1 tabulates the weighted system availabilities from figure B.3.18.1. Table B.3.18.2 tabulates the losses in system availability that occurred as a result of losing a single satellite (derived from the failure system availability analysis).

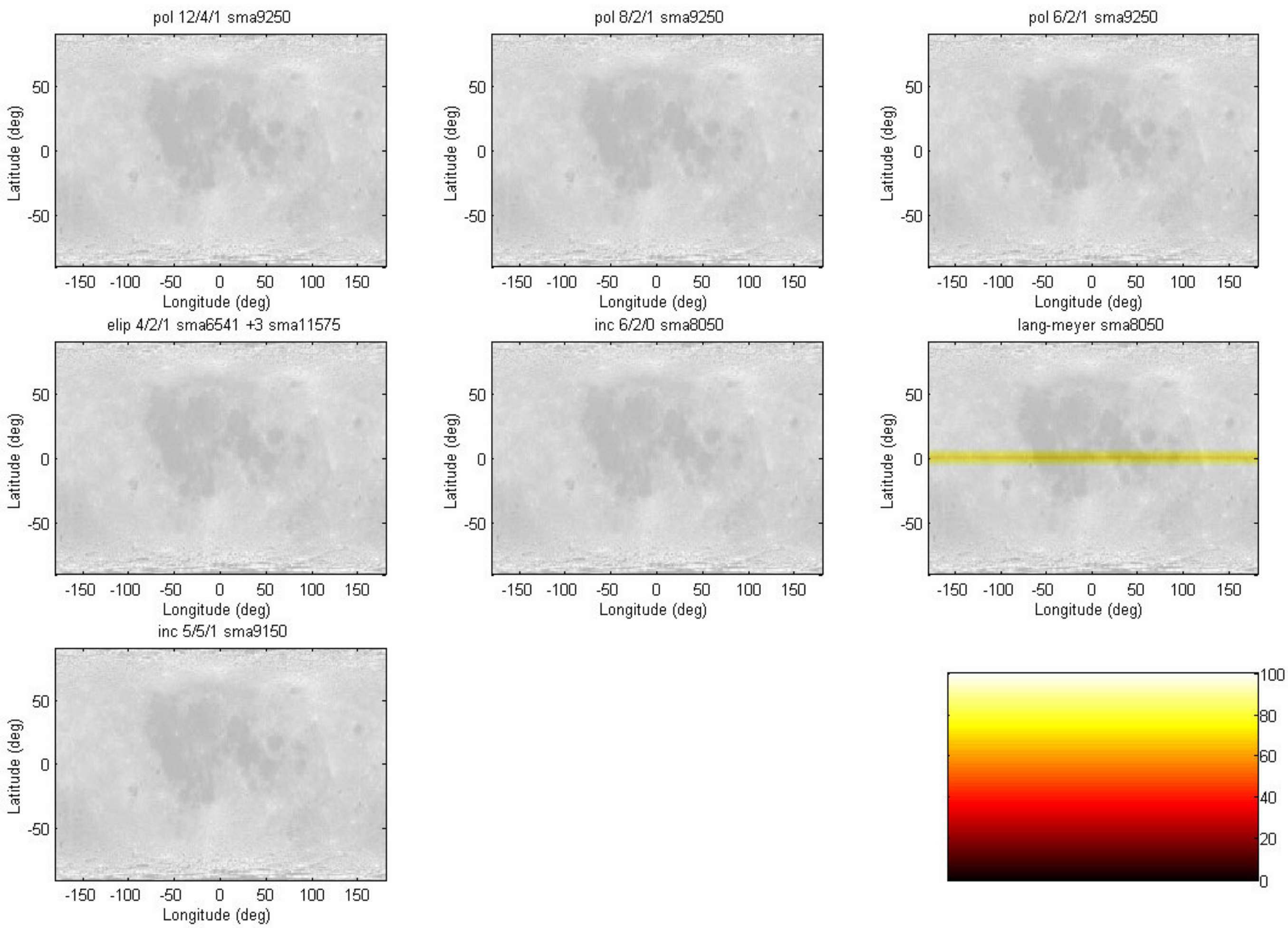

Figure B.3.18.1.—Lunar system availability results.

TABLE B.3.18.1.—WEIGHTED LUNAR SYSTEM AVAILABILITY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	100.00	100.00	100.00	100.00	100.00
Pol 8/2/1 SMA 9250	99.95	100.00	99.93	99.95	99.91
Pol 6/2/1 SMA 9250	99.94	100.00	99.92	99.94	99.90
Elip 4/2/1 SMA 6541 + 3 SMA 11575	99.97	100.00	99.96	99.97	99.95
Inc 6/2/0 SMA 8050	100.00	100.00	100.00	100.00	100.00
Lang-Meyer SMA 8050	97.87	100.00	97.17	97.87	96.18
Inc 5/5/1 SMA 9150	99.96	100.00	99.96	99.96	99.97

TABLE B.3.18.2.—WEIGHTED LUNAR SYSTEM AVAILABILITY DECREASES FROM FAILURE MODE SYSTEM AVAILABILITY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.15	0.00	1.53	1.13	2.10
Pol 6/2/1 SMA 9250	3.69	0.00	4.92	3.66	6.60
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.63	5.42	0.28	0.63	0.08
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.63	0.00	0.28	0.64	0.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	4.00	0.00	5.24	3.98	5.16
Inc 6/2/0 SMA 8050	4.09	0.00	4.10	4.13	3.52
Lang-Meyer SMA 8050 - v1	3.98	0.00	5.31	3.94	6.81
Lang-Meyer SMA 8050 - v2	4.72	12.26	2.62	4.75	1.76
Inc 5/5/1 SMA 9150	8.52	7.21	7.60	8.52	6.18

Appendix C—System Latency/Failure System Latency Results

C.1 User Minimum Elevation Angle of 5°

***C.1.1 System availability of 90 percent, no terrain, one-way latency*.**—Figure C.1.1.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode without terrain information. For figure C.1.1.1, regions in black represent 160 min of latency. Table C.1.1.1 tabulates the weighted system latency for figure C.1.1.1. Table C.1.1.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

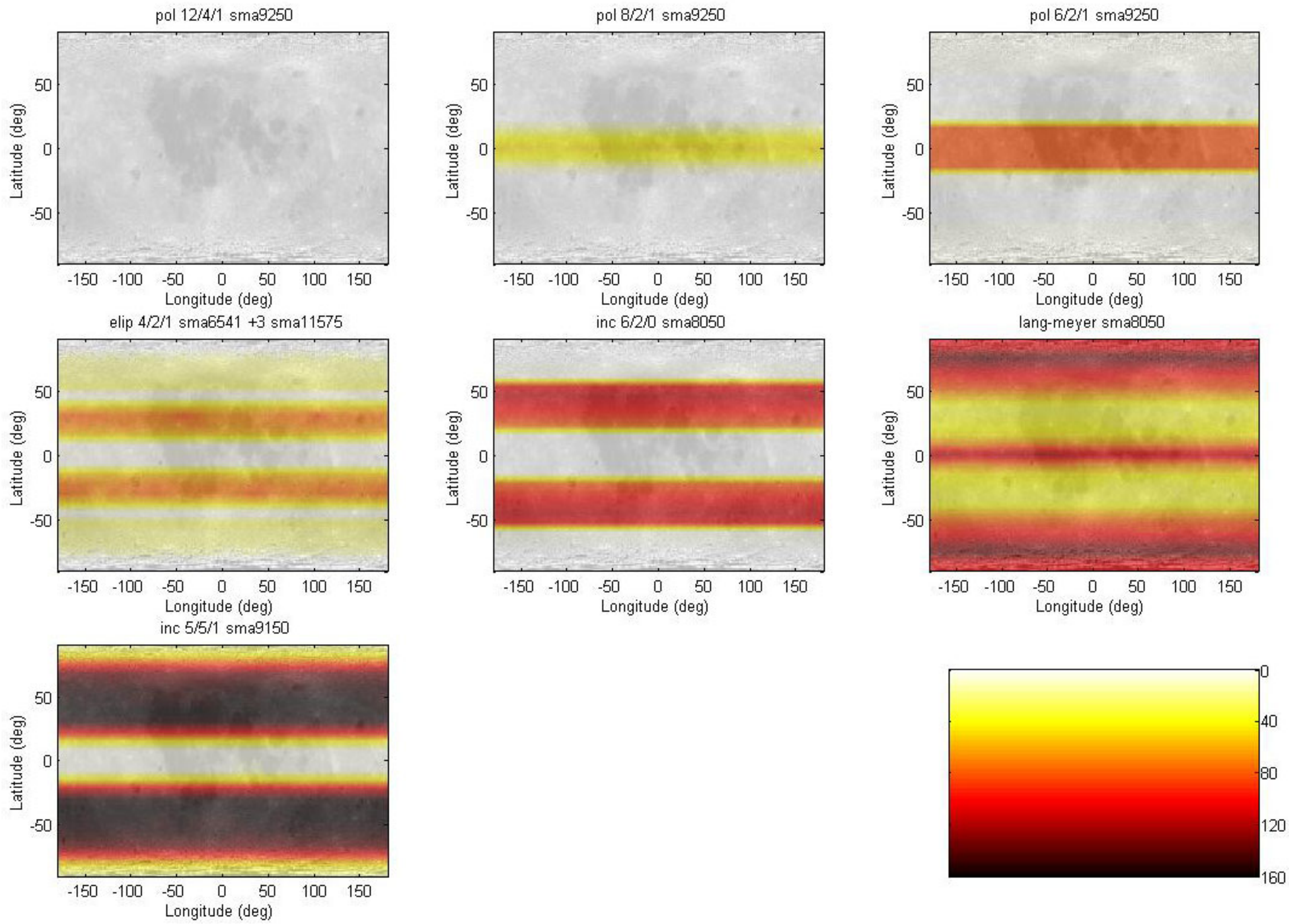

Figure C.1.1.1.—Lunar system latency results.

TABLE C.1.1.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	10.27	0.00	13.64	10.26	18.52
Pol 6/2/1 SMA 9250	29.39	5.00	37.90	29.39	51.29
Elip 4/2/1 SMA 6541 + 3 SMA 11575	35.07	0.00	40.08	35.22	44.35
Inc 6/2/0 SMA 8050	51.64	0.00	56.65	51.64	37.91
Lang-Meyer SMA 8050	66.27	109.17	53.63	66.34	55.87
Inc 5/5/1 SMA 9150	101.83	35.00	92.17	101.97	68.73

TABLE C.1.1.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	20.91	5.00	26.10	20.93	31.29
Pol 6/2/1 SMA 9250	61.24	45.21	55.84	61.18	41.96
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	43.05	50.00	45.91	43.06	48.08
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	42.82	0.00	45.86	42.56	47.02
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	59.30	25.00	71.80	59.02	78.04
Inc 6/2/0 SMA 8050	54.76	155.00	46.25	55.06	54.94
Lang-Meyer SMA 8050 - v1	60.45	0.00	73.46	60.15	73.45
Lang-Meyer SMA 8050 - v2	61.42	75.83	65.09	61.71	54.97
Inc 5/5/1 SMA 9150	85.25	125.00	79.27	85.18	83.16

***C.1.2 System availability of 90 percent, good terrain, one-way latency*.**—Figure C.1.2.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode with terrain information. For figure C.1.2.1, regions in black represent 120 min of latency. Table C.1.2.1 tabulates the weighted system latency for figure C.1.2.1. Table C.1.2.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

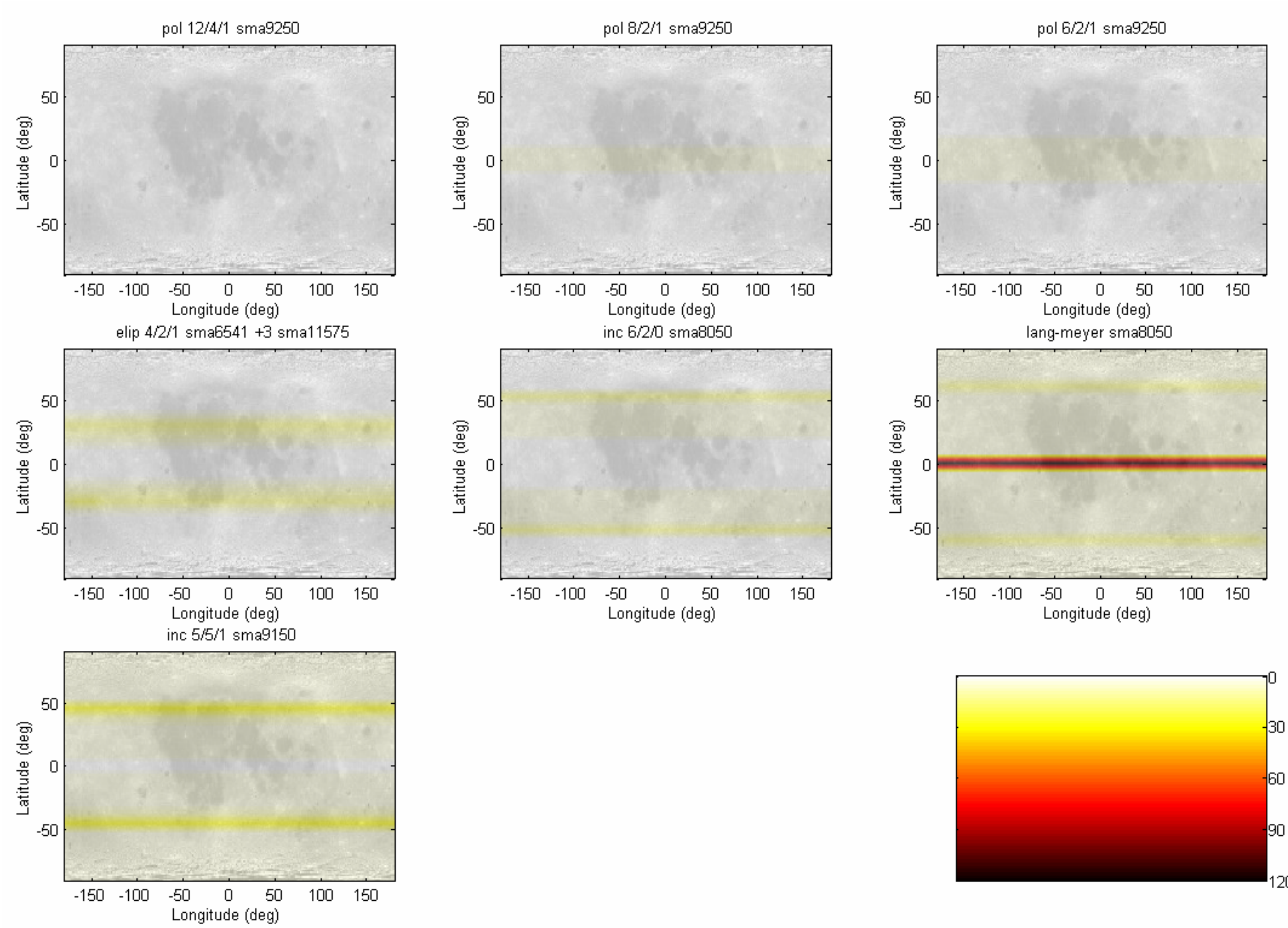

Figure C.1.2.1.—Lunar system latency results.

TABLE C.1.2.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.98	0.00	1.30	0.98	1.76
Pol 6/2/1 SMA 9250	1.61	0.00	2.14	1.61	2.89
Elip 4/2/1 SMA 6541 + 3 SMA 11575	4.09	0.00	5.40	4.12	6.37
Inc 6/2/0 SMA 8050	3.35	0.00	2.86	3.35	2.11
Lang-Meyer SMA 8050	12.99	5.00	14.74	12.98	18.07
Inc 5/5/1 SMA 9150	7.51	5.00	8.33	7.51	4.41

TABLE C.1.2.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.63	0.00	0.84	0.63	1.13
Pol 6/2/1 SMA 9250	4.93	5.00	4.90	4.94	4.78
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.61	5.00	1.60	2.61	1.76
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.61	0.00	1.60	2.61	1.76
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	4.99	10.00	3.88	4.99	3.70
Inc 6/2/0 SMA 8050	2.65	5.00	2.14	2.67	2.89
Lang-Meyer SMA 8050 - v1	1.08	0.00	1.26	0.92	1.63
Lang-Meyer SMA 8050 - v2	1.84	20.83	0.00	1.90	0.00
Inc 5/5/1 SMA 9150	6.09	0.00	8.02	6.15	1.61

C.1.3 System availability of 90 percent, no terrain, two-way latency.—Figure C.1.3.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode without terrain information. For figure C.1.3.1, regions in black represent 150 min of latency. Table C.1.3.1 tabulates the weighted system latency for figure C.1.3.1. Table C.1.3.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

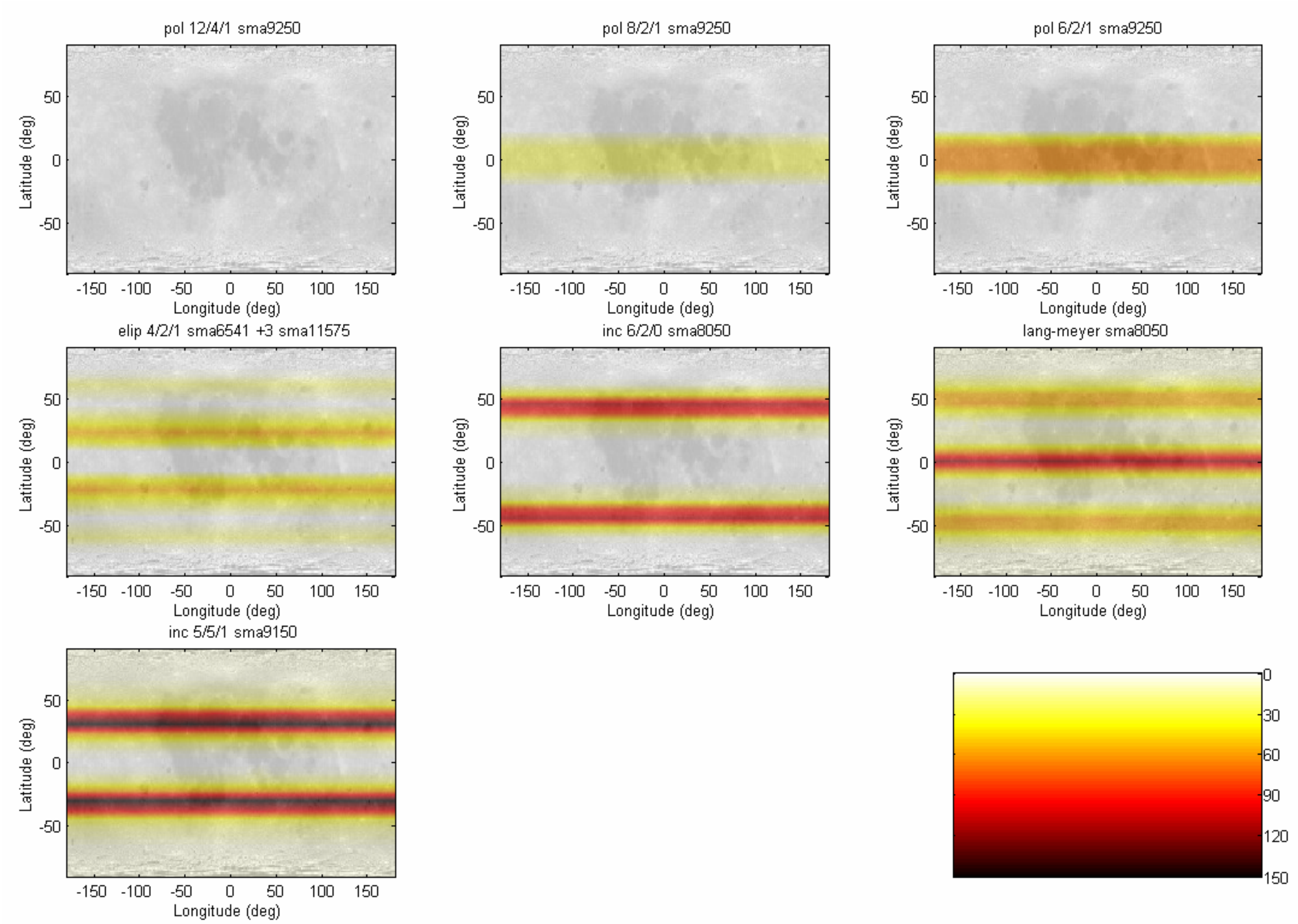

Figure C.1.3.1.—Lunar system latency results.

TABLE C.1.3.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	6.79	0.00	9.01	6.79	12.19
Pol 6/2/1 SMA 9250	18.12	0.00	24.01	18.15	32.49
Elip 4/2/1 SMA 6541 + 3 SMA 11575	19.44	0.00	22.70	19.41	27.74
Inc 6/2/0 SMA 8050	25.64	0.00	29.89	25.64	6.25
Lang-Meyer SMA 8050	34.27	5.00	36.45	34.36	34.27
Inc 5/5/1 SMA 9150	43.05	5.00	54.01	43.04	49.27

TABLE C.1.3.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	2.87	0.00	3.84	2.85	5.13
Pol 6/2/1 SMA 9250	15.26	25.00	14.07	15.12	14.66
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	14.66	10.00	17.00	14.57	21.71
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	14.42	0.00	16.83	14.15	20.89
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	11.46	10.00	13.52	11.59	16.01
Inc 6/2/0 SMA 8050	8.79	5.00	9.99	8.82	8.33
Lang-Meyer SMA 8050 - v1	13.36	0.00	14.99	13.15	8.41
Lang-Meyer SMA 8050 - v2	4.17	25.00	2.22	4.18	2.04
Inc 5/5/1 SMA 9150	18.97	0.00	23.34	18.98	25.07

***C.1.4 System availability of 90 percent, good terrain, two-way latency*.**—Figure C.1.4.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode with terrain information. For figure C.1.4.1, regions in black represent 120 min of latency. Table C.1.4.1 tabulates the weighted system latency for figure C.1.4.1. Table C.1.4.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

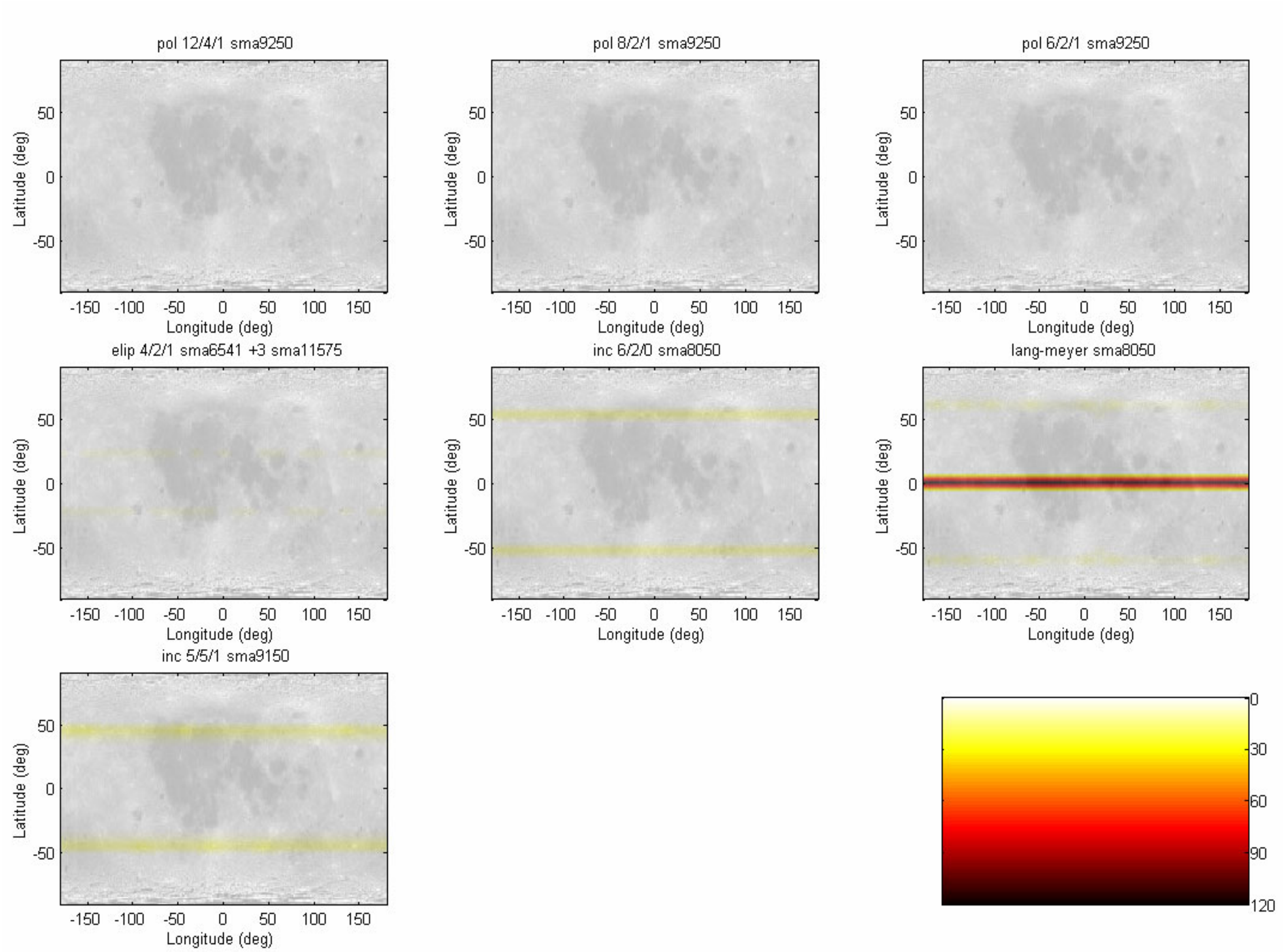

Figure C.1.4.1.—Lunar system latency results.

TABLE C.1.4.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 6/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575	0.44	0.00	0.53	0.50	0.65
Inc 6/2/0 SMA 8050	1.20	0.00	0.00	1.20	0.00
Lang-Meyer SMA 8050	8.11	0.00	10.17	8.13	13.66
Inc 5/5/1 SMA 9150	1.98	0.00	2.63	1.97	0.00

TABLE C.1.4.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 6/2/1 SMA 9250	1.39	0.00	1.82	1.41	2.56
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.49	0.00	0.27	0.43	0.44
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.49	0.00	0.27	0.43	0.44
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	0.73	0.00	1.03	0.67	1.46
Inc 6/2/0 SMA 8050	0.46	0.00	0.62	0.46	0.00
Lang-Meyer SMA 8050 - v1	0.93	0.00	0.47	0.82	0.70
Lang-Meyer SMA 8050 - v2	1.97	15.83	0.00	1.99	0.00
Inc 5/5/1 SMA 9150	3.68	0.00	4.87	3.69	1.02

C.1.5 System availability of 99 percent, no terrain, one-way latency.—Figure C.1.5.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode without terrain information. For figure C.1.5.1, regions in black represent 335 min of latency. Table C.1.5.1 tabulates the weighted system latency for figure C.1.5.1. Table C.1.5.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

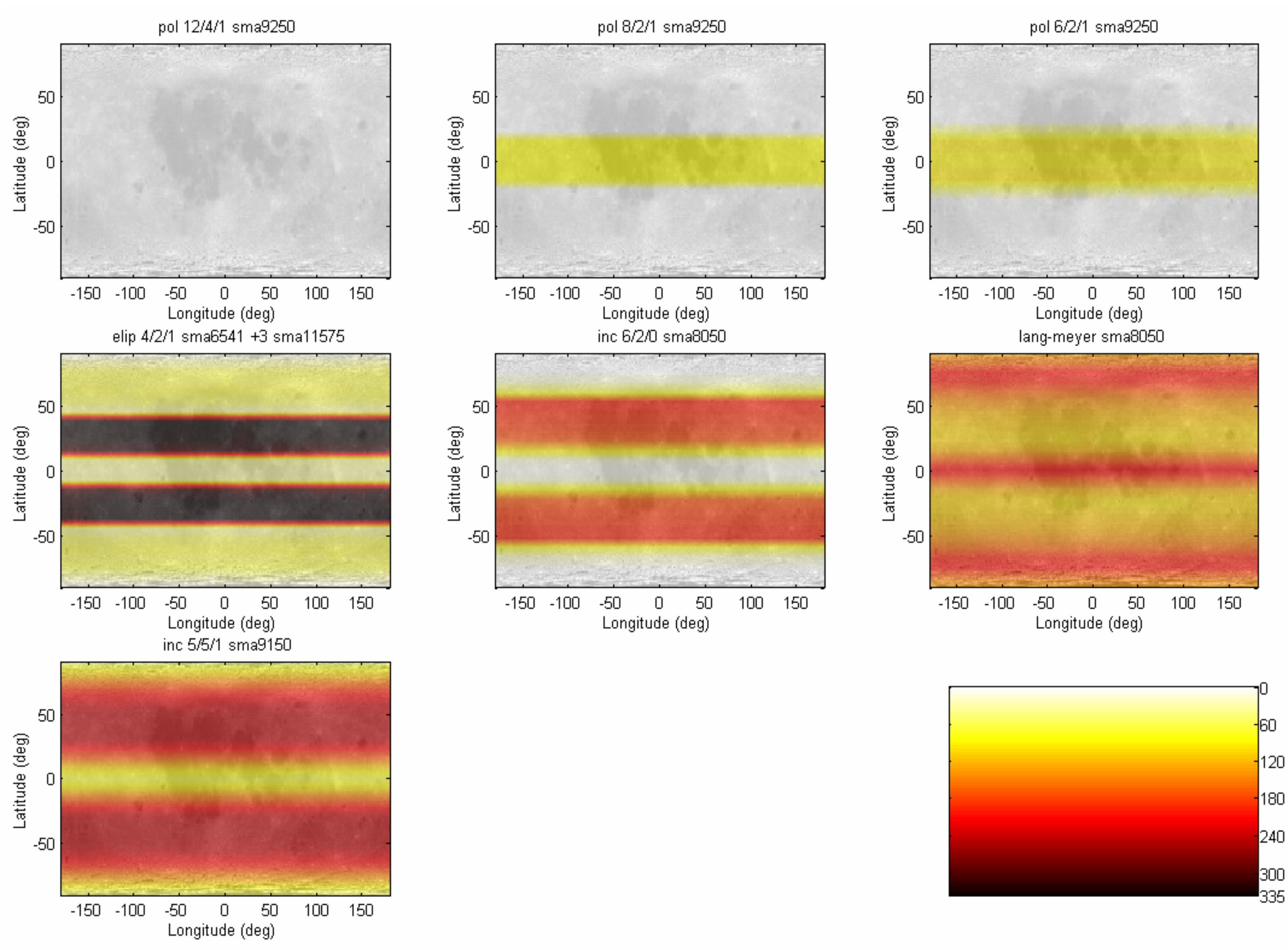

Figure C.1.5.1.—Lunar system latency results.

TABLE C.1.5.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	29.60	0.00	37.76	29.60	50.27
Pol 6/2/1 SMA 9250	38.95	5.00	50.15	38.87	66.05
Elip 4/2/1 SMA 6541 + 3 SMA 11575	175.96	29.79	214.89	175.71	223.12
Inc 6/2/0 SMA 8050	114.64	2.50	123.72	114.61	99.49
Lang-Meyer SMA 8050	142.42	160.21	133.29	142.56	138.03
Inc 5/5/1 SMA 9150	188.96	90.00	184.27	189.03	162.81

TABLE C.1.5.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.05	0.00	0.10	0.03	0.23
Pol 8/2/1 SMA 9250	72.64	20.00	78.74	72.33	80.96
Pol 6/2/1 SMA 9250	204.71	110.00	225.09	204.63	237.18
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	66.32	50.63	59.07	65.78	61.55
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	66.15	12.50	58.54	66.15	60.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	153.02	45.00	181.02	154.25	192.72
Inc 6/2/0 SMA 8050	132.83	232.50	123.70	133.37	116.63
Lang-Meyer SMA 8050 - v1	69.93	0.00	84.34	69.65	88.73
Lang-Meyer SMA 8050 - v2	130.77	94.79	132.15	130.92	113.58
Inc 5/5/1 SMA 9150	167.40	125.00	156.75	167.29	131.59

C.1.6 System availability of 99 percent, good terrain, one-way latency.—Figure C.1.6.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode with terrain information. For figure C.1.6.1, regions in black represent 220 min of latency. Table C.1.6.1 tabulates the weighted system latency for figure C.1.6.1. Table C.1.6.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

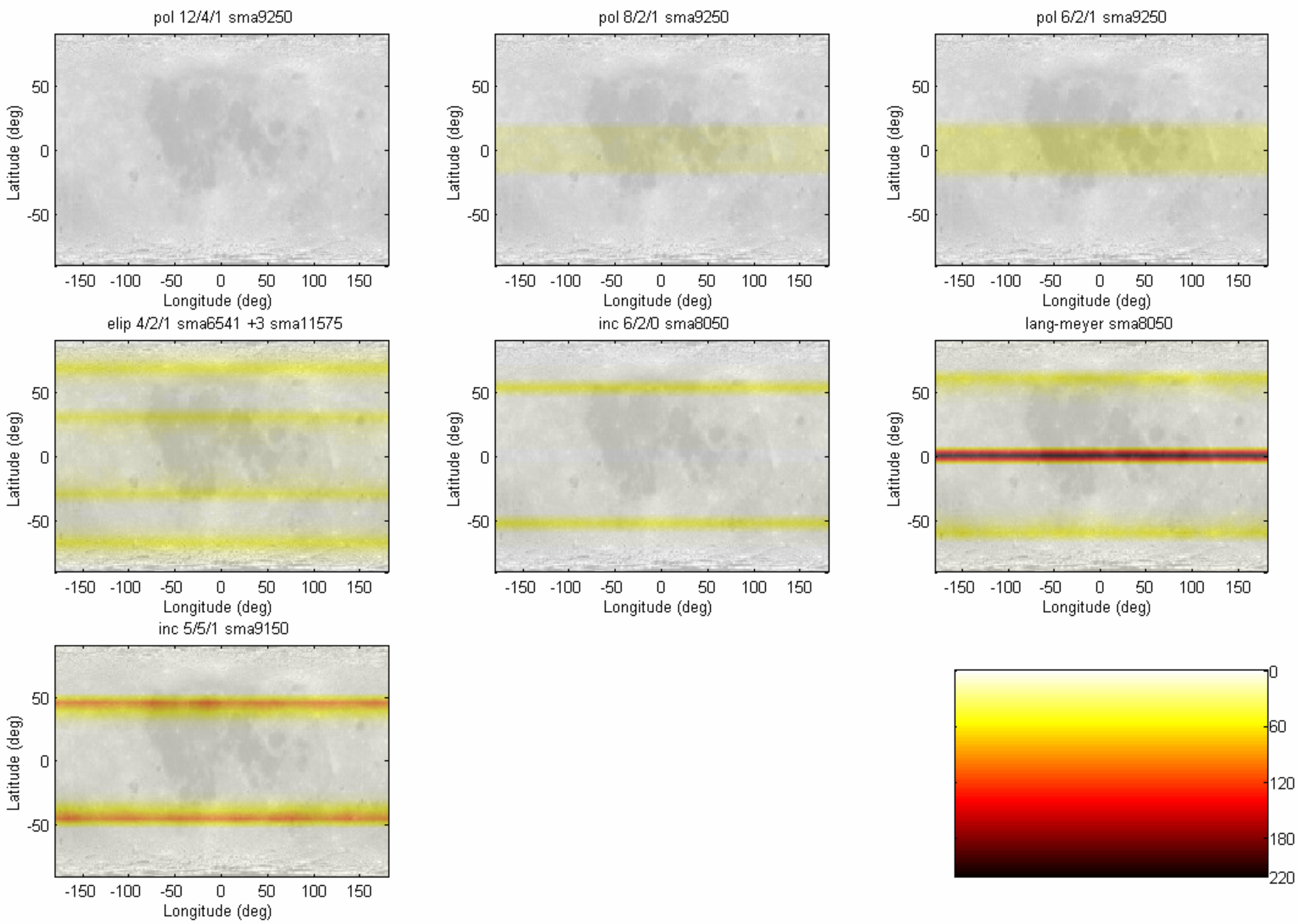

Figure C.1.6.1—Lunar system latency results.

TABLE C.1.6.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	5.98	0.00	7.92	6.00	11.11
Pol 6/2/1 SMA 9250	10.31	0.00	13.66	10.33	18.56
Elip 4/2/1 SMA 6541 + 3 SMA 11575	18.49	10.00	16.97	18.52	19.99
Inc 6/2/0 SMA 8050	8.39	0.00	4.57	8.39	4.41
Lang-Meyer SMA 8050	24.43	5.00	24.41	24.37	30.31
Inc 5/5/1 SMA 9150	20.11	5.00	25.03	20.14	7.04

TABLE C.1.6.2—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	14.60	0.00	18.35	14.32	22.05
Pol 6/2/1 SMA 9250	74.20	24.38	94.65	73.55	122.30
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	9.03	9.58	5.46	8.92	6.89
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	8.85	0.00	5.18	8.86	6.35
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	135.73	0.00	176.94	137.03	192.95
Inc 6/2/0 SMA 8050	97.69	5.00	112.53	98.50	80.18
Lang-Meyer SMA 8050 - v1	55.34	0.00	72.21	55.16	91.98
Lang-Meyer SMA 8050 - v2	71.94	144.38	46.54	72.33	26.89
Inc 5/5/1 SMA 9150	175.20	65.00	167.58	175.23	139.36

C.1.7 System availability of 99 percent, no terrain, two-way latency.—Figure C.1.7.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode without terrain information. For figure C.1.7.1, regions in black represent 305 min of latency. Table C.1.7.1 tabulates the weighted system latency for figure C.1.7.1. Table C.1.7.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

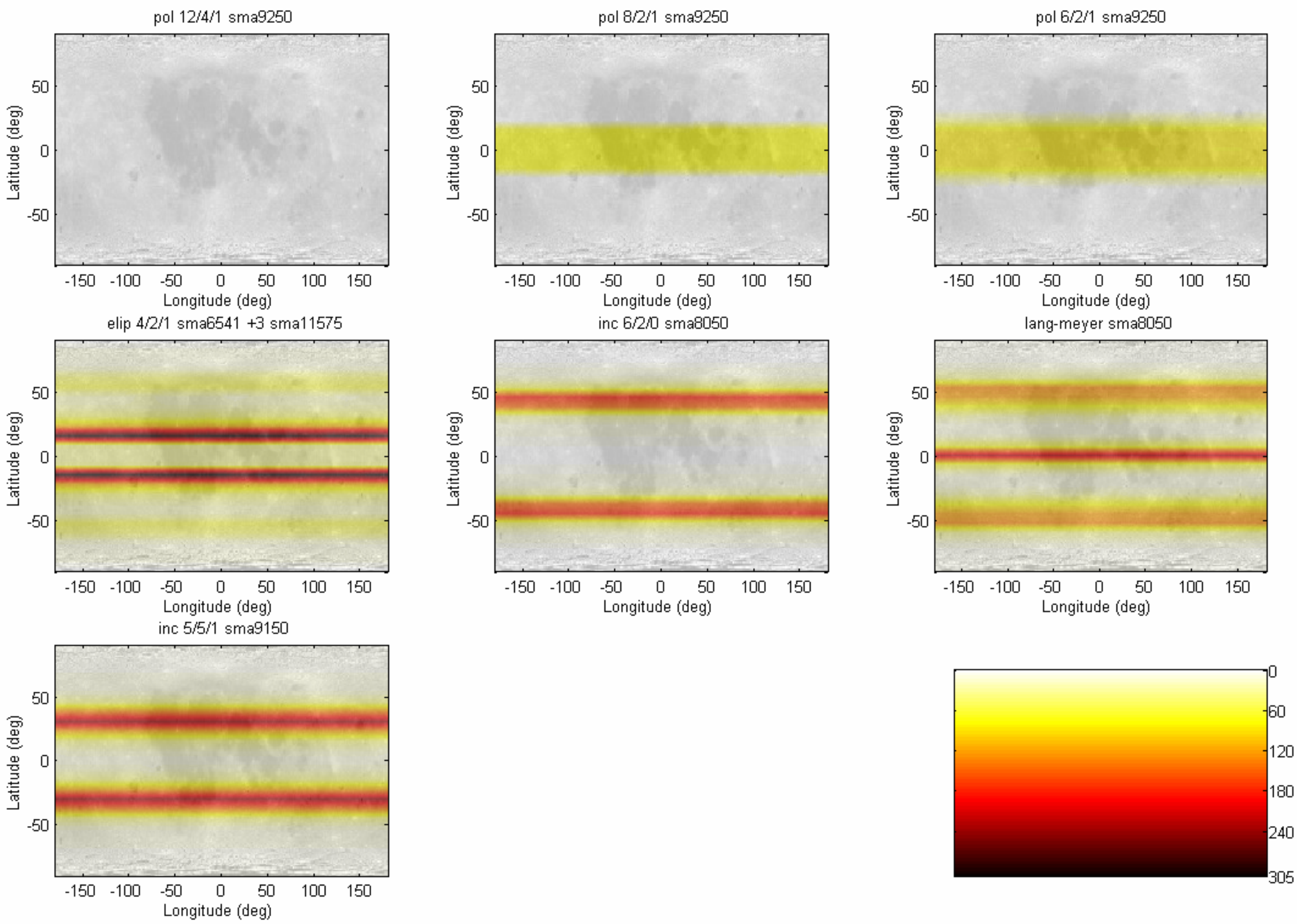

Figure C.1.7.1.—Lunar system latency results.

TABLE C.1.7.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	25.24	0.00	33.49	25.25	45.26
Pol 6/2/1 SMA 9250	32.87	0.00	43.61	32.89	58.70
Elip 4/2/1 SMA 6541 + 3 SMA 11575	76.07	10.00	89.67	75.96	113.57
Inc 6/2/0 SMA 8050	44.06	0.00	51.21	44.07	11.73
Lang-Meyer SMA 8050	60.92	5.00	62.67	60.96	51.00
Inc 5/5/1 SMA 9150	69.48	5.00	88.78	69.47	87.87

TABLE C.1.7.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	24.46	20.00	23.38	24.01	22.09
Pol 6/2/1 SMA 9250	112.02	68.75	117.50	111.45	128.04
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	32.20	13.13	31.54	31.94	40.04
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	31.67	0.00	30.60	31.61	39.44
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	162.87	0.00	214.52	164.24	229.24
Inc 6/2/0 SMA 8050	108.43	5.00	115.41	109.28	108.54
Lang-Meyer SMA 8050 - v1	90.17	0.00	118.26	89.87	136.94
Lang-Meyer SMA 8050 - v2	52.99	145.00	30.64	53.15	34.27
Inc 5/5/1 SMA 9150	157.81	66.04	144.30	157.95	104.33

***C.1.8 System availability of 99 percent, good terrain, two-way latency*.**—Figure C.1.8.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode with terrain information. For figure C.1.8.1, regions in black represent 220 min of latency. Table C.1.8.1 tabulates the weighted system latency for figure C.1.8.1. Table C.1.8.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

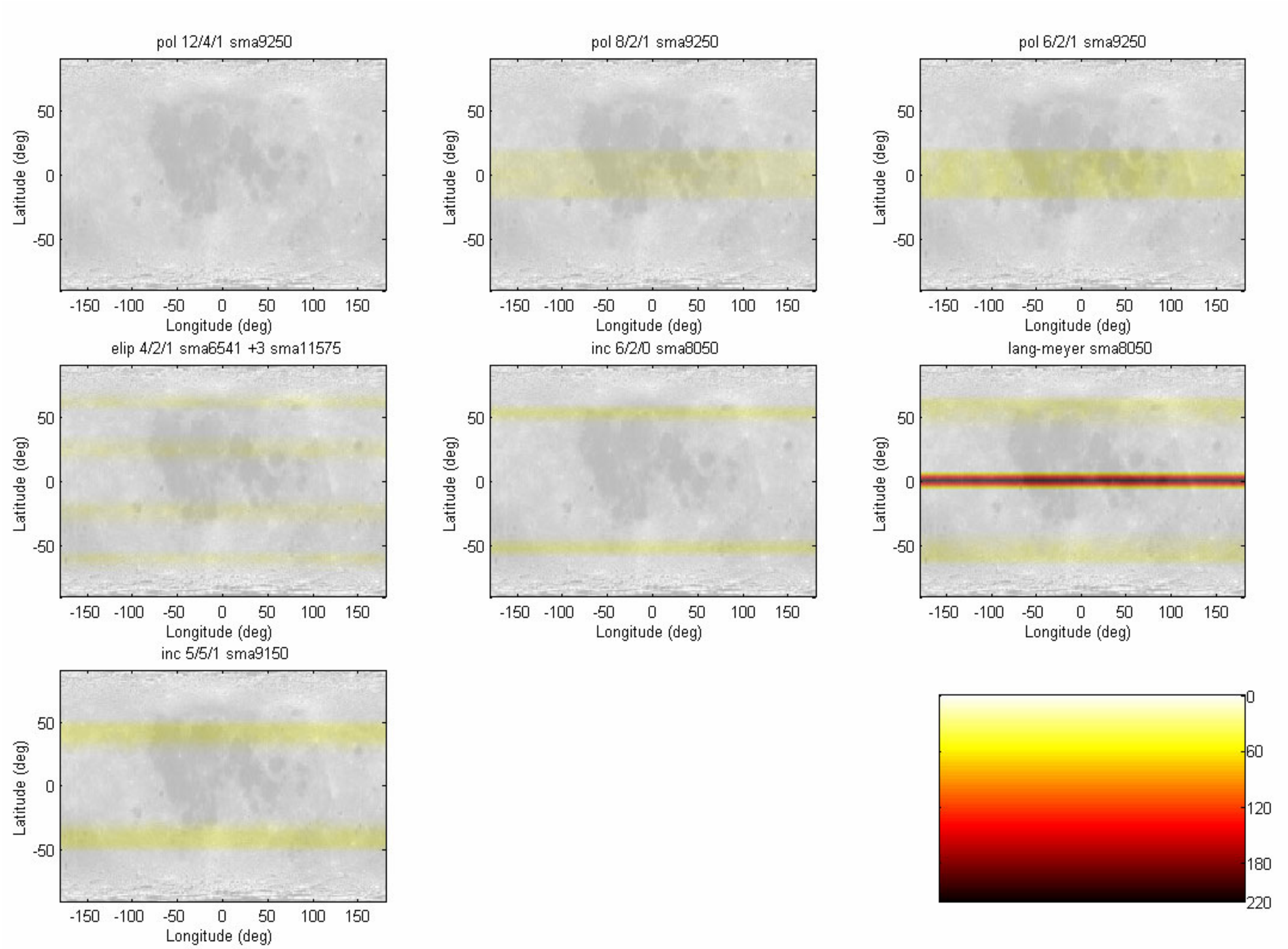

Figure C.1.8.1.—Lunar system latency results.

TABLE C.1.8.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	5.13	0.00	6.87	5.07	9.15
Pol 6/2/1 SMA 9250	7.80	0.00	10.30	7.85	13.54
Elip 4/2/1 SMA 6541 + 3 SMA 11575	5.09	0.00	4.91	5.15	6.66
Inc 6/2/0 SMA 8050	2.86	0.00	0.62	2.86	0.00
Lang-Meyer SMA 8050	18.45	0.00	20.37	18.47	25.90
Inc 5/5/1 SMA 9150	6.90	0.00	9.13	6.93	2.14

TABLE C.1.8.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	9.22	0.00	12.42	9.04	17.03
Pol 6/2/1 SMA 9250	69.56	15.00	89.92	69.01	118.51
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	8.98	10.00	5.16	9.00	6.82
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	8.90	0.00	5.52	8.60	8.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	136.83	0.00	179.30	137.90	196.21
Inc 6/2/0 SMA 8050	95.57	0.00	108.76	96.44	77.96
Lang-Meyer SMA 8050 - v1	50.79	0.00	67.40	50.52	86.73
Lang-Meyer SMA 8050 - v2	70.42	140.00	43.42	70.86	25.33
Inc 5/5/1 SMA 9150	178.32	60.00	173.29	178.37	134.22

C.2 User Minimum Elevation Angle of 10°

C.2.1 System availability of 90 percent, no terrain, one-way latency.—Figure C.2.1.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode without terrain information. For figure C.2.1.1, regions in black represent 175 min of latency. Table C.2.1.1 tabulates the weighted system latency for figure C.2.1.1. Table C.2.1.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

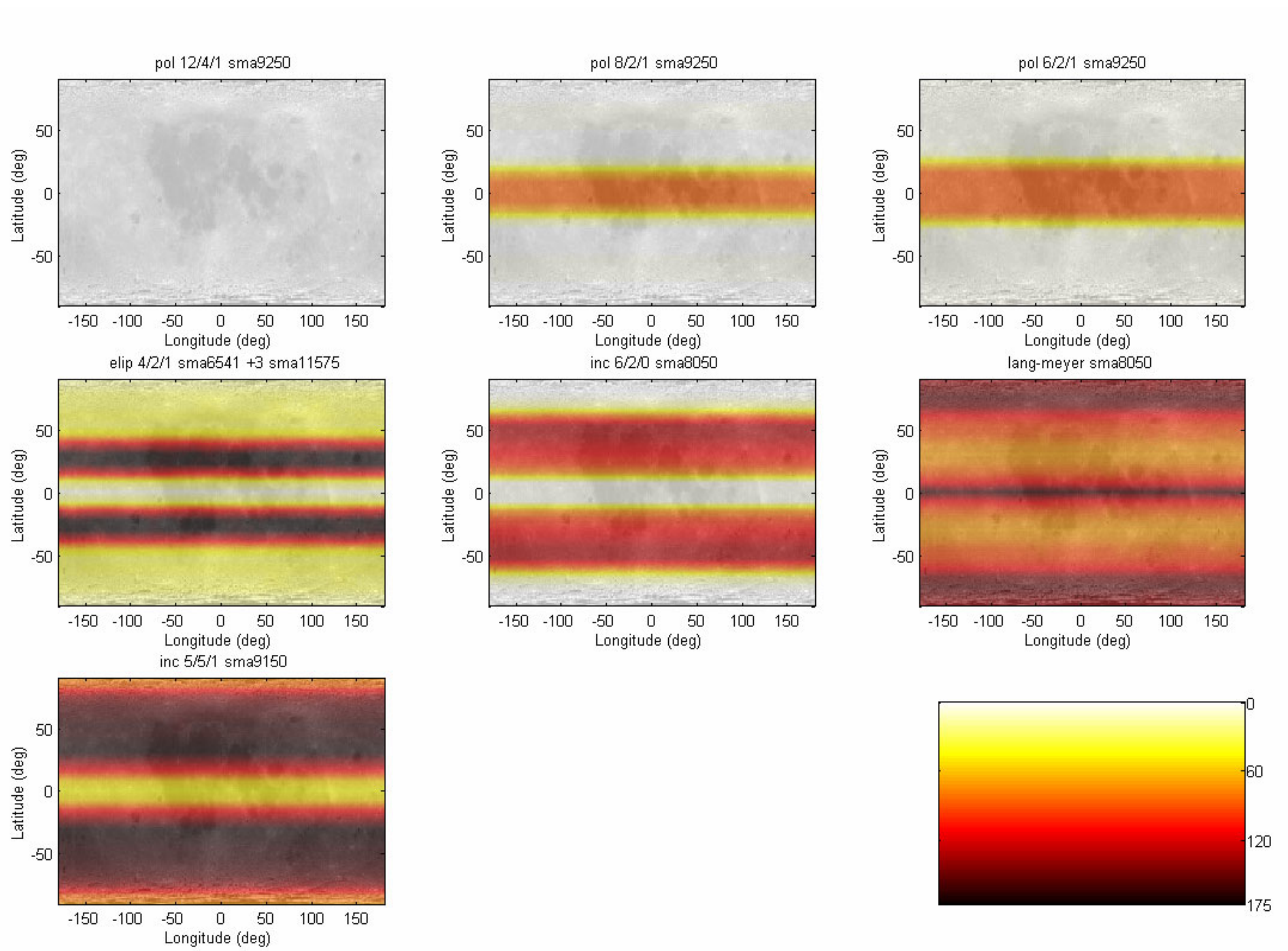

Figure C.2.1.1.—Lunar system latency results.

TABLE C.2.1.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	27.64	0.00	35.39	27.64	47.89
Pol 6/2/1 SMA 9250	39.41	5.00	50.73	39.35	66.75
Elip 4/2/1 SMA 6541 + 3 SMA 11575	85.05	20.00	102.66	85.18	106.56
Inc 6/2/0 SMA 8050	76.58	0.00	79.11	76.57	62.99
Lang-Meyer SMA 8050	99.28	144.79	92.26	99.25	95.58
Inc 5/5/1 SMA 9150	130.24	90.00	122.93	130.26	107.13

TABLE C.2.1.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	14.74	15.83	15.48	14.63	15.09
Pol 6/2/1 SMA 9250	68.87	84.17	61.19	68.75	47.36
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	45.06	60.00	45.78	44.80	47.24
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	44.60	5.00	45.20	44.25	45.07
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	61.77	30.00	71.39	61.92	72.98
Inc 6/2/0 SMA 8050	51.67	160.00	43.71	52.02	48.53
Lang-Meyer SMA 8050 - v1	52.65	0.00	64.91	52.24	70.34
Lang-Meyer SMA 8050 - v2	71.60	75.21	68.94	72.01	59.41
Inc 5/5/1 SMA 9150	93.58	110.00	80.94	93.55	76.59

__C.2.2 System availability of 90 percent, good terrain, one-way latency__.—Figure C.2.2.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode with terrain information. For figure C.2.2.1, regions in black represent 165 min of latency. Table C.2.2.1 tabulates the weighted system latency for figure C.2.2.1. Table C.2.2.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

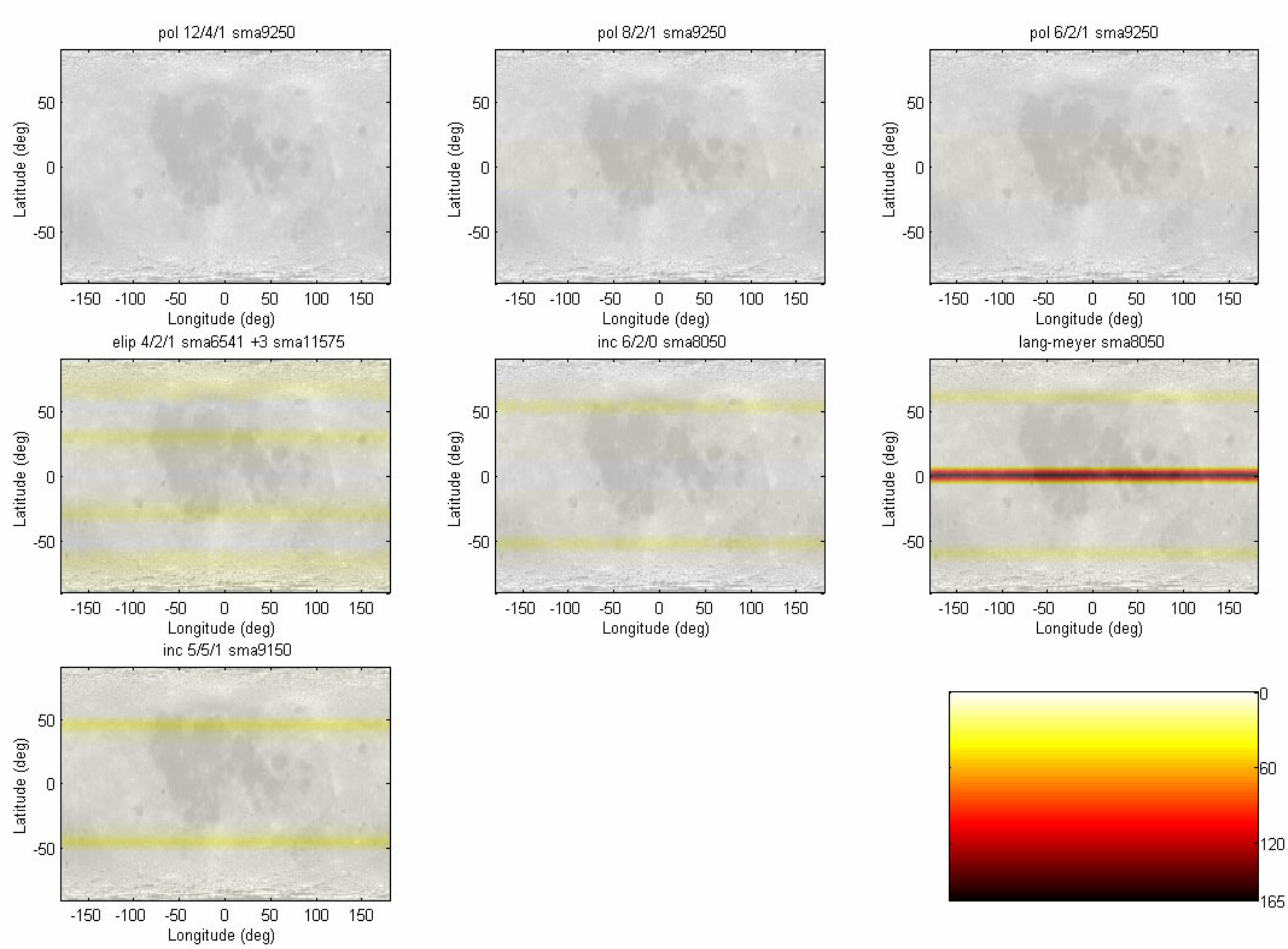

Figure C.2.2.1.—Lunar system latency results.

TABLE C.2.2.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.61	0.00	2.14	1.61	2.89
Pol 6/2/1 SMA 9250	2.22	0.00	2.94	2.22	3.98
Elip 4/2/1 SMA 6541 + 3 SMA 11575	7.77	10.00	7.63	7.76	8.56
Inc 6/2/0 SMA 8050	4.88	0.00	3.70	4.87	3.24
Lang-Meyer SMA 8050	16.28	5.00	18.68	16.26	23.48
Inc 5/5/1 SMA 9150	7.84	5.00	8.77	7.84	5.00

TABLE C.2.2.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.61	0.00	0.80	0.61	1.09
Pol 6/2/1 SMA 9250	6.53	5.00	7.04	6.54	7.86
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	3.04	0.00	1.43	3.04	1.57
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	3.03	0.00	1.43	3.08	1.46
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	5.05	0.00	5.11	5.08	5.20
Inc 6/2/0 SMA 8050	2.40	5.00	1.92	2.43	1.76
Lang-Meyer SMA 8050 - v1	7.54	0.00	10.23	7.35	13.93
Lang-Meyer SMA 8050 - v2	8.18	56.04	0.00	8.28	0.00
Inc 5/5/1 SMA 9150	23.53	0.00	20.09	23.64	6.16

C.2.3 System availability of 90 percent, no terrain, two-way latency.—Figure C.2.3.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode without terrain information. For figure C.2.3.1, regions in black represent 165 min of latency. Table C.2.3.1 tabulates the weighted system latency for figure C.2.3.1. Table C.2.3.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

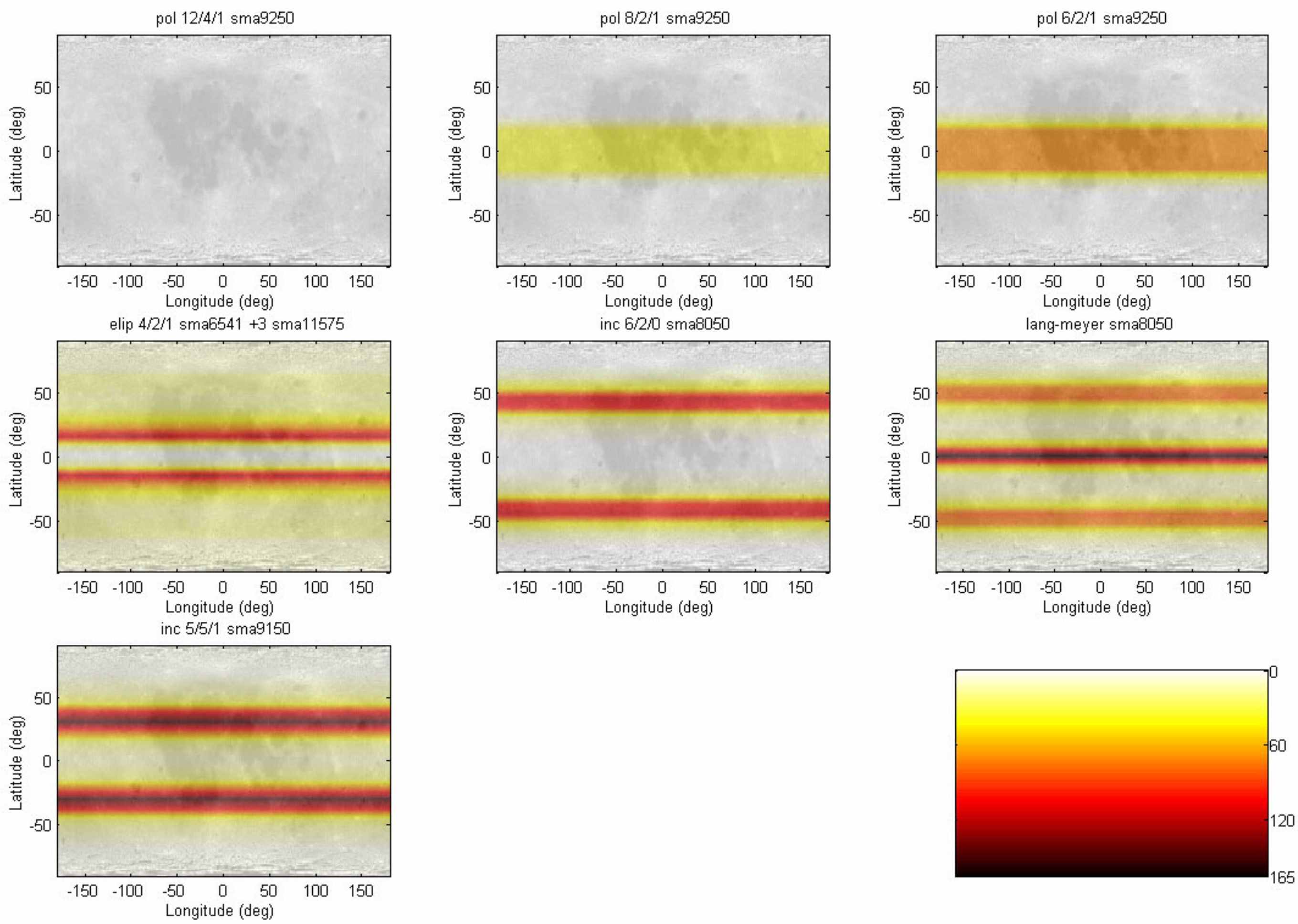

Figure C.2.3.1.—Lunar system latency results.

TABLE C.2.3.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	12.49	0.00	16.57	12.49	22.43
Pol 6/2/1 SMA 9250	26.14	0.00	34.70	26.14	46.96
Elip 4/2/1 SMA 6541 + 3 SMA 11575	36.67	10.00	43.43	36.73	52.21
Inc 6/2/0 SMA 8050	29.95	0.00	33.85	29.97	8.41
Lang-Meyer SMA 8050	42.90	5.00	45.86	42.86	41.72
Inc 5/5/1 SMA 9150	49.20	5.00	62.16	49.20	59.44

TABLE C.2.3.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	9.97	10.00	11.64	9.86	14.62
Pol 6/2/1 SMA 9250	17.90	25.00	15.77	17.84	15.97
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	18.86	0.00	20.58	18.55	27.24
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	18.52	0.00	20.07	18.35	26.41
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	19.08	0.00	25.58	18.82	30.83
Inc 6/2/0 SMA 8050	12.22	5.00	15.13	12.32	13.53
Lang-Meyer SMA 8050 - v1	19.14	0.00	24.37	18.83	23.31
Lang-Meyer SMA 8050 - v2	10.27	56.04	2.84	10.42	1.02
Inc 5/5/1 SMA 9150	38.28	0.00	38.23	38.41	36.97

C.2.4 System availability of 90 percent, good terrain, two-way latency.—Figure C.2.4.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode with terrain information. For figure C.2.4.1, regions in black represent 165 min of latency. Table C.2.4.1 tabulates the weighted system latency for figure C.2.4.1. Table C.2.4.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

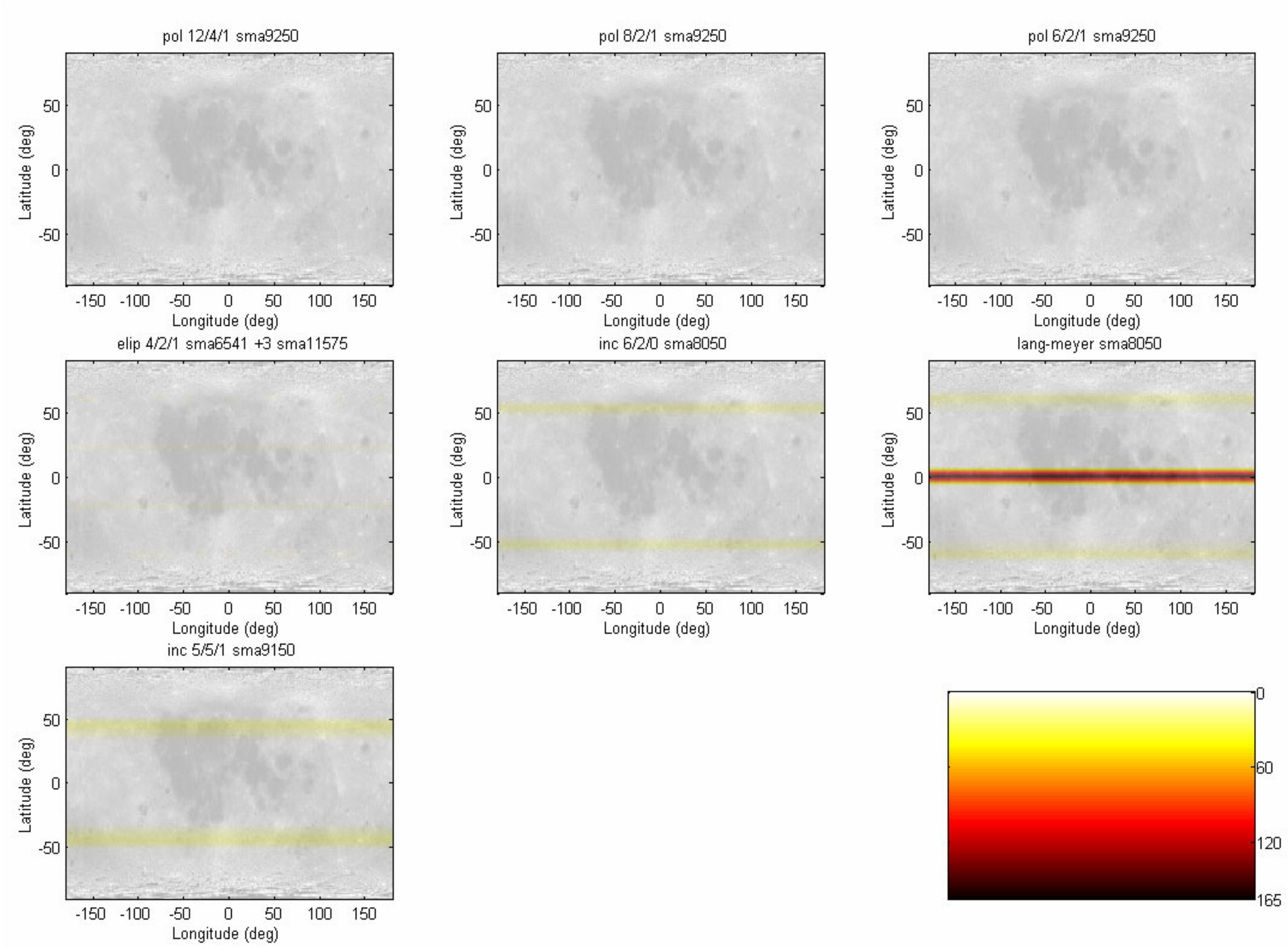

Figure C.2.4.1.—Lunar system latency results.

TABLE C.2.4.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 6/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575	0.74	0.00	0.80	0.72	1.09
Inc 6/2/0 SMA 8050	1.20	0.00	0.00	1.20	0.00
Lang-Meyer SMA 8050	12.01	0.00	14.12	11.99	19.07
Inc 5/5/1 SMA 9150	2.89	0.00	3.84	2.89	0.00

TABLE C.2.4.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 6/2/1 SMA 9250	3.66	0.00	4.91	3.61	6.84
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	0.57	0.00	0.03	0.62	0.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	0.54	0.00	0.06	0.54	0.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	1.70	0.00	2.19	1.69	2.85
Inc 6/2/0 SMA 8050	0.86	0.00	0.62	0.86	0.00
Lang-Meyer SMA 8050 - v1	6.39	0.00	8.79	6.12	12.09
Lang-Meyer SMA 8050 - v2	7.07	51.04	0.61	7.16	0.00
Inc 5/5/1 SMA 9150	17.00	0.00	12.76	17.05	5.44

***C.2.5 System availability of 99 percent, no terrain, one-way latency*.**—Figure C.2.5.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode without terrain information. For figure C.2.5.1, regions in black represent 360 min of latency. Table C.2.5.1 tabulates the weighted system latency for figure C.2.5.1. Table C.2.5.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

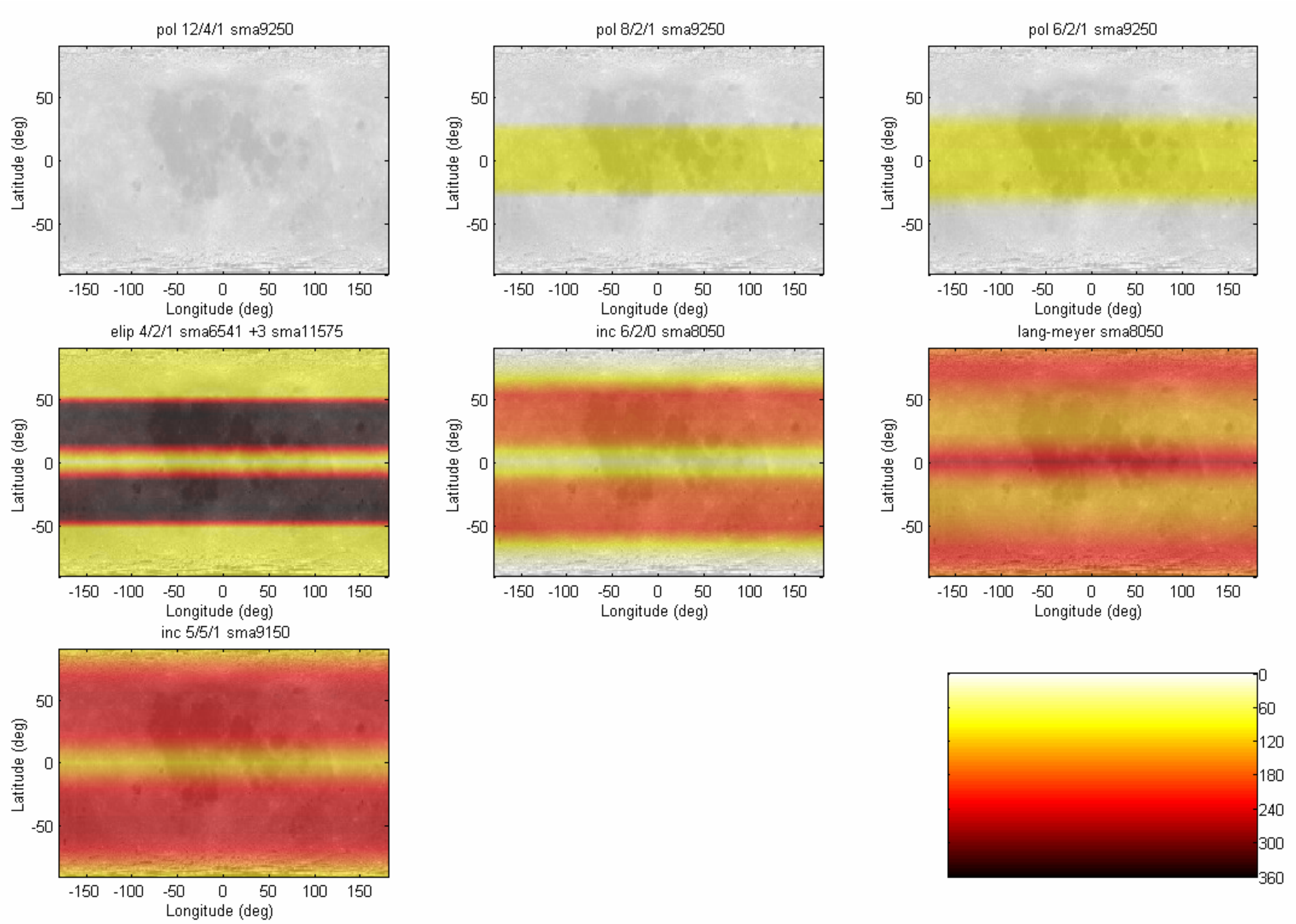

Figure C.2.5.1.—Lunar system latency results.

TABLE C.2.5.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	39.70	5.00	51.07	39.69	67.27
Pol 6/2/1 SMA 9250	53.41	5.00	69.26	53.41	90.09
Elip 4/2/1 SMA 6541 + 3 SMA 11575	237.33	75.00	289.47	237.06	269.46
Inc 6/2/0 SMA 8050	147.40	10.00	154.89	147.36	140.04
Lang-Meyer SMA 8050	170.61	195.21	163.76	170.55	170.72
Inc 5/5/1 SMA 9150	213.54	143.96	208.31	213.56	194.52

TABLE C.2.5.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	9.99	0.00	13.16	10.07	17.92
Pol 8/2/1 SMA 9250	98.82	15.00	104.14	98.73	108.07
Pol 6/2/1 SMA 9250	230.13	120.00	253.39	230.08	272.85
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	52.37	35.00	33.62	52.02	44.91
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	51.99	62.08	33.09	51.45	42.92
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	194.99	15.00	236.75	195.43	231.99
Inc 6/2/0 SMA 8050	150.60	228.96	146.76	150.99	134.61
Lang-Meyer SMA 8050 - v1	69.82	0.00	88.74	69.81	98.53
Lang-Meyer SMA 8050 - v2	159.12	107.50	155.61	159.23	135.88
Inc 5/5/1 SMA 9150	210.29	141.67	204.18	210.16	172.35

C.2.6 System availability of 99 percent, good terrain, one-way latency.—Figure C.2.6.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode with terrain information. For figure C.2.6.1, regions in black represent 260 min of latency. Table C.2.6.1 tabulates the weighted system latency for figure C.2.6.1. Table C.2.6.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

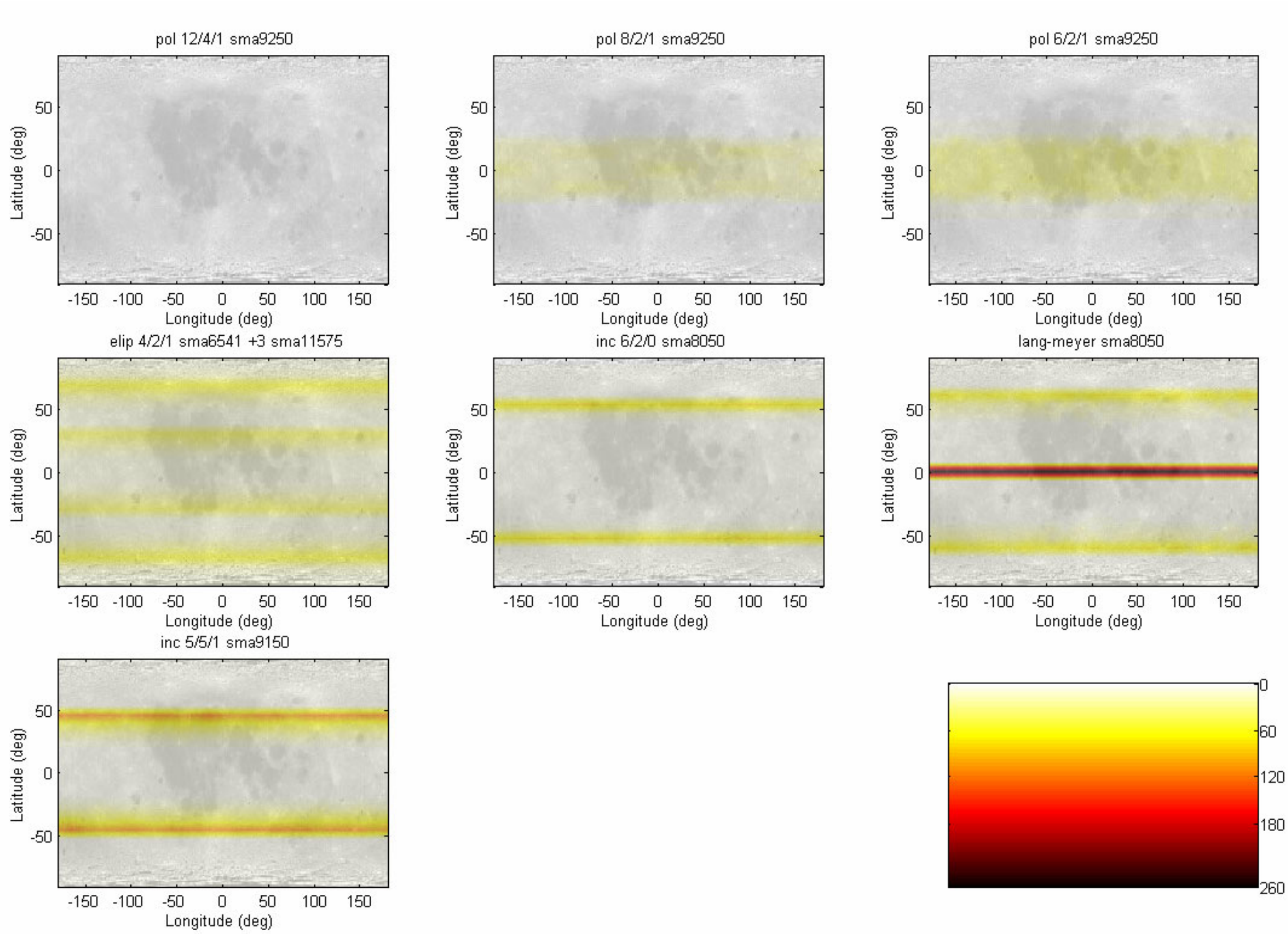

Figure C.2.6.1.—Lunar system latency results.

TABLE C.2.6.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	8.51	0.00	11.31	8.50	15.54
Pol 6/2/1 SMA 9250	13.75	0.00	18.27	13.73	24.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575	21.73	10.00	19.45	21.66	22.84
Inc 6/2/0 SMA 8050	11.56	5.00	6.23	11.51	5.00
Lang-Meyer SMA 8050	28.68	5.00	28.57	28.52	35.02
Inc 5/5/1 SMA 9150	22.77	5.00	28.48	22.86	10.17

TABLE C.2.6.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	1.61	0.00	2.14	1.61	2.89
Pol 8/2/1 SMA 9250	31.32	3.33	39.97	31.06	51.10
Pol 6/2/1 SMA 9250	112.38	30.63	144.19	111.90	189.62
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	14.41	65.00	9.54	14.37	8.20
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	14.58	5.00	9.70	14.69	8.88
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	217.67	0.00	286.54	218.15	273.13
Inc 6/2/0 SMA 8050	157.75	0.00	174.34	158.37	147.75
Lang-Meyer SMA 8050 - v1	76.22	0.00	100.24	76.17	122.93
Lang-Meyer SMA 8050 - v2	108.94	179.79	78.51	109.46	55.88
Inc 5/5/1 SMA 9150	228.37	120.00	220.88	228.47	196.73

C.2.7 System availability of 99 percent, no terrain, two-way latency.—Figure C.2.7.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode without terrain information. For figure C.2.7.1, regions in black represent 320 min of latency. Table C.2.7.1 tabulates the weighted system latency for figure C.2.7.1. Table C.2.7.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

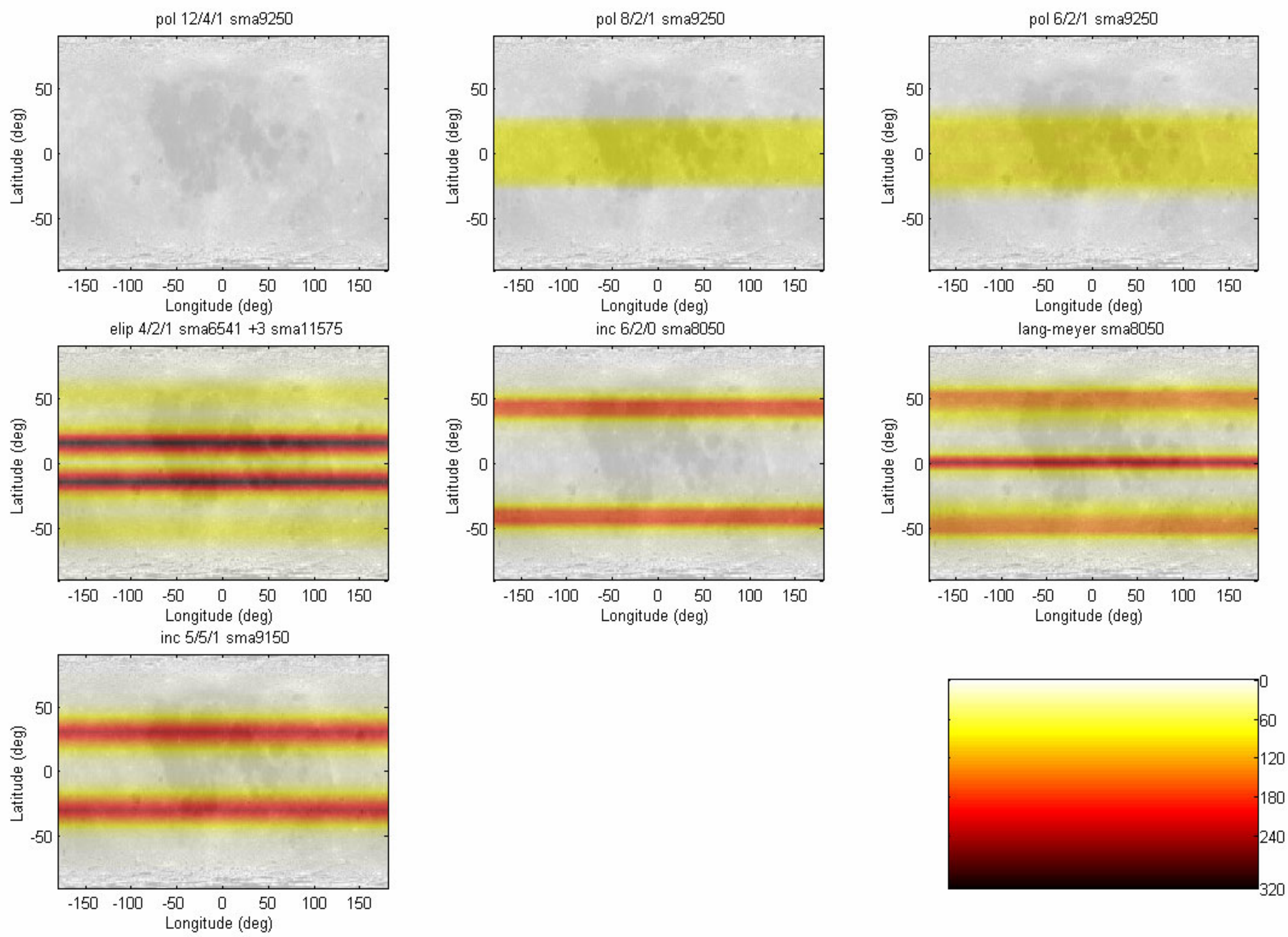

Figure C.2.7.1.—Lunar system latency results.

TABLE C.2.7.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	35.25	0.00	46.79	35.25	63.32
Pol 6/2/1 SMA 9250	45.12	0.00	59.92	45.10	79.17
Elip 4/2/1 SMA 6541 + 3 SMA 11575	102.48	10.00	123.19	102.32	151.84
Inc 6/2/0 SMA 8050	49.08	5.00	57.00	49.08	15.75
Lang-Meyer SMA 8050	71.23	5.00	73.74	71.38	60.46
Inc 5/5/1 SMA 9150	78.33	5.00	100.49	78.34	102.82

TABLE C.2.7.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	2.81	0.00	3.73	2.82	4.99
Pol 8/2/1 SMA 9250	49.74	20.00	51.08	49.39	53.18
Pol 6/2/1 SMA 9250	141.50	75.00	153.76	141.09	177.60
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	26.46	66.04	22.09	26.41	26.19
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	26.20	0.00	21.83	26.16	25.73
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	221.25	0.00	292.85	221.95	277.64
Inc 6/2/0 SMA 8050	157.35	0.00	164.49	157.67	159.52
Lang-Meyer SMA 8050 - v1	102.63	0.00	135.87	102.40	161.25
Lang-Meyer SMA 8050 - v2	76.75	179.79	46.93	76.86	48.86
Inc 5/5/1 SMA 9150	205.30	120.00	189.96	205.38	150.10

C.2.8 System availability of 99 percent, good terrain, two-way latency.—Figure C.2.8.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode with terrain information. For figure C.2.8.1, regions in black represent 260 min of latency. Table C.2.8.1 tabulates the weighted system latency for figure C.2.8.1. Table C.2.8.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

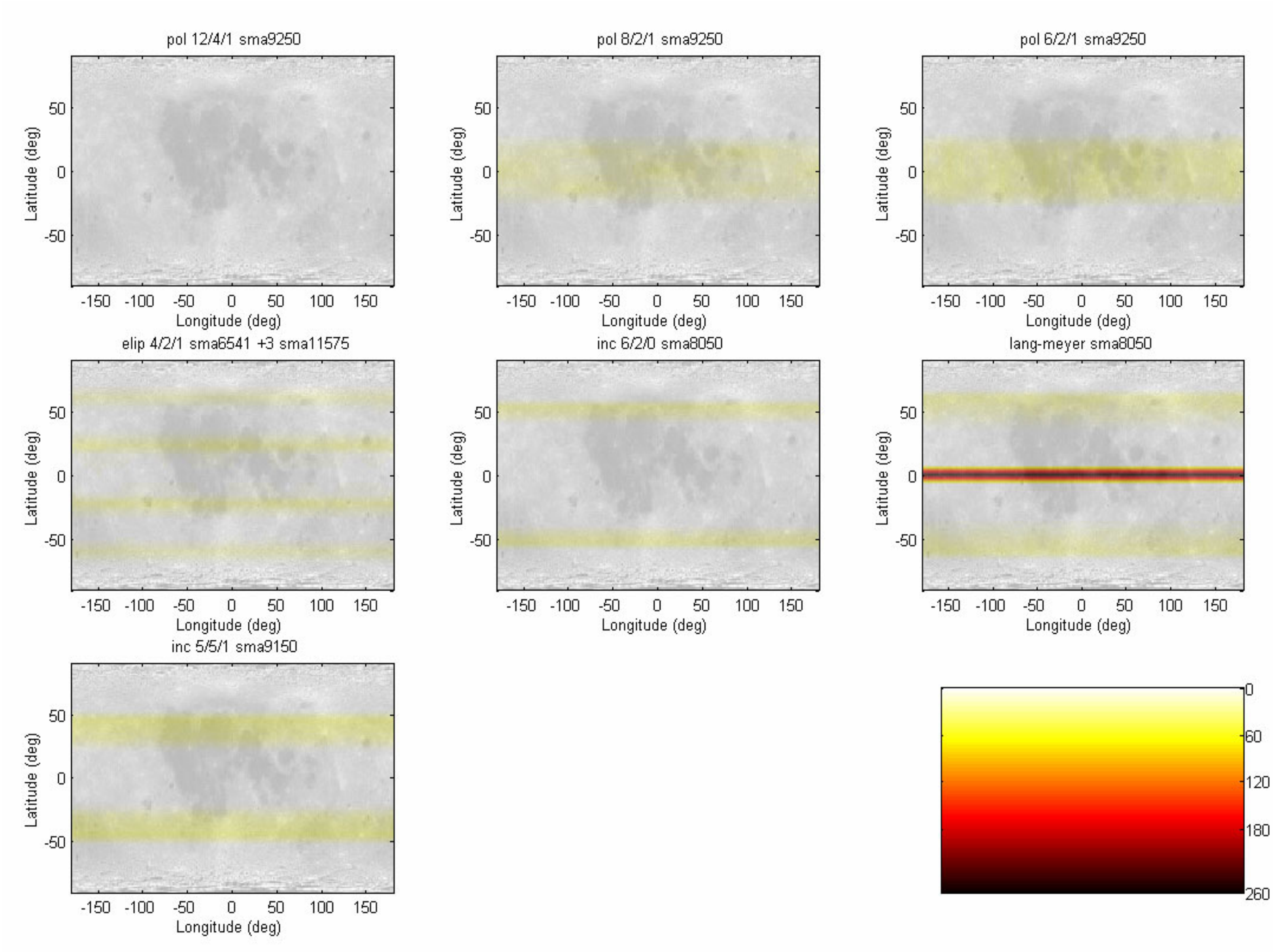

Figure C.2.8.1.—Lunar system latency results.

TABLE C.2.8.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	7.52	0.00	9.99	7.51	13.43
Pol 6/2/1 SMA 9250	9.93	0.00	13.19	9.93	17.71
Elip 4/2/1 SMA 6541 + 3 SMA 11575	7.53	0.00	7.37	7.51	9.98
Inc 6/2/0 SMA 8050	3.77	0.00	1.82	3.76	0.00
Lang-Meyer SMA 8050	22.24	0.00	25.01	22.23	30.61
Inc 5/5/1 SMA 9150	9.56	0.00	12.70	9.55	5.88

TABLE C.2.8.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	25.28	0.00	33.61	24.96	44.73
Pol 6/2/1 SMA 9250	107.35	15.00	139.48	107.04	184.45
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	14.50	65.63	9.25	14.38	7.80
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	14.43	0.00	8.99	14.56	7.69
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	217.34	0.00	286.90	218.09	274.24
Inc 6/2/0 SMA 8050	156.01	0.00	169.28	156.60	143.45
Lang-Meyer SMA 8050 - v1	71.14	0.00	94.23	70.90	117.46
Lang-Meyer SMA 8050 - v2	107.22	174.79	74.03	107.65	52.86
Inc 5/5/1 SMA 9150	231.28	115.00	226.31	231.41	190.68

C.3 User Minimum Elevation Angle of 15°

C.3.1 System availability of 90 percent, no terrain, one-way latency.—Figure C.3.1.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode without terrain information. For figure C.3.1.1, regions in black represent 215 min of latency. Table C.3.1.1 tabulates the weighted system latency for figure C.3.1.1. Table C.3.1.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

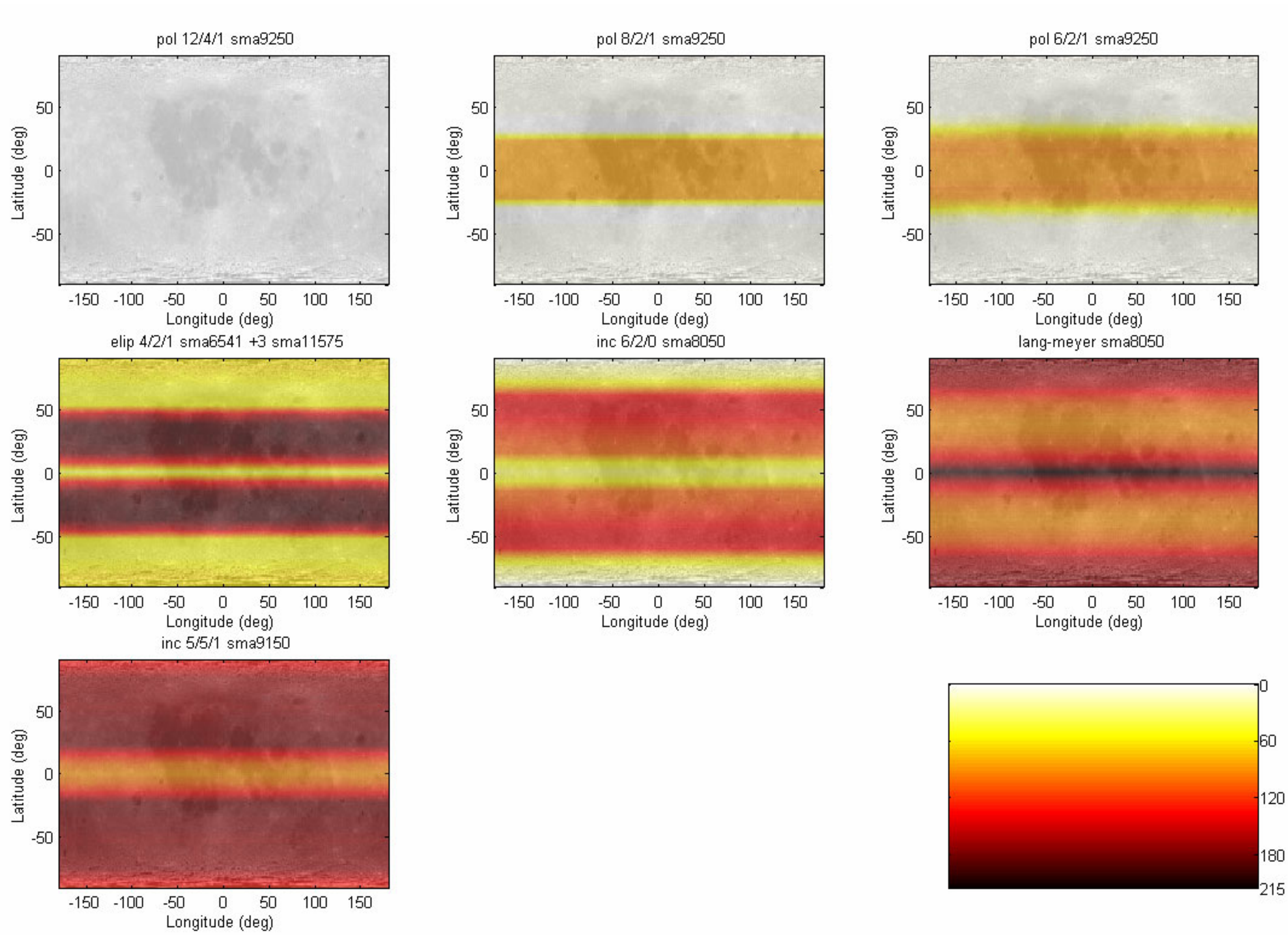

Figure C.3.1.1.—Lunar system latency results.

TABLE C.3.1.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	39.94	5.00	51.37	39.94	68.69
Pol 6/2/1 SMA 9250	51.03	5.00	66.05	51.06	85.01
Elip 4/2/1 SMA 6541 + 3 SMA 11575	135.92	65.00	162.68	136.01	157.82
Inc 6/2/0 SMA 8050	101.87	20.00	101.39	101.89	89.46
Lang-Meyer SMA 8050	124.38	175.00	121.25	124.46	131.20
Inc 5/5/1 SMA 9150	154.71	145.00	149.75	154.92	140.76

TABLE C.3.1.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.01	0.00	0.03	0.00	0.12
Pol 8/2/1 SMA 9250	15.53	15.00	15.39	15.54	12.95
Pol 6/2/1 SMA 9250	90.94	102.71	88.04	90.33	80.99
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	34.46	40.00	28.28	34.36	31.22
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	34.13	25.00	28.09	33.83	30.43
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	69.15	10.00	81.69	68.79	82.28
Inc 6/2/0 SMA 8050	53.15	155.00	46.90	53.50	48.27
Lang-Meyer SMA 8050 - v1	53.63	0.00	66.80	53.43	72.11
Lang-Meyer SMA 8050 - v2	90.84	88.54	78.66	91.10	65.30
Inc 5/5/1 SMA 9150	122.07	130.00	102.64	121.61	81.63

C.3.2 System availability of 90 percent, good terrain, one-way latency.—Figure C.3.2.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode with terrain information. For figure C.3.2.1, regions in black represent 215 min of latency. Table C.3.2.1 tabulates the weighted system latency for figure C.3.2.1. Table C.3.2.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

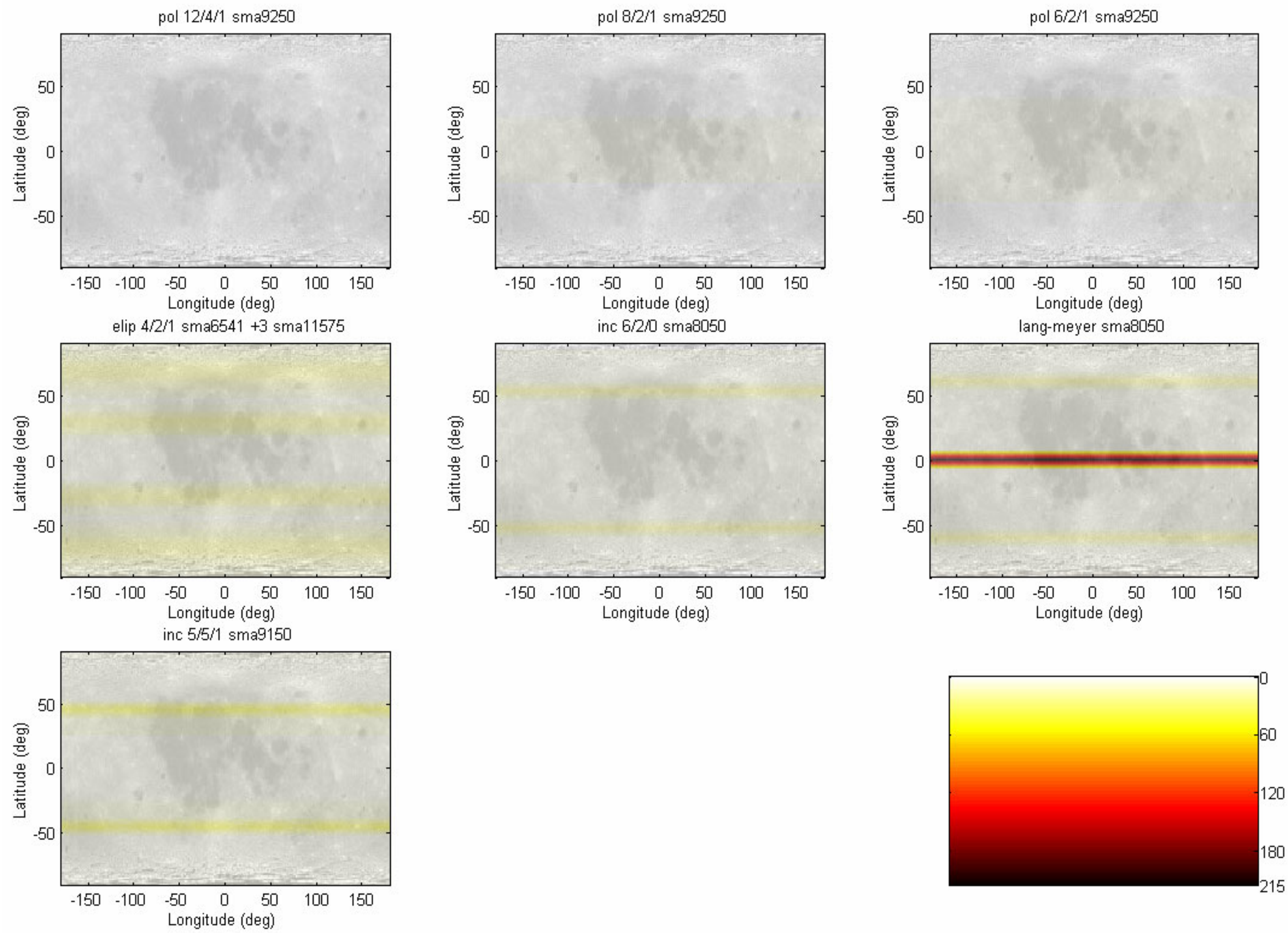

Figure C.3.2.1.—Lunar system latency results.

TABLE C.3.2.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	2.22	0.00	2.94	2.22	3.98
Pol 6/2/1 SMA 9250	3.30	0.00	4.38	3.30	5.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575	10.67	10.00	9.56	10.67	10.23
Inc 6/2/0 SMA 8050	6.20	5.00	5.00	6.20	5.00
Lang-Meyer SMA 8050	19.47	5.00	22.97	19.42	29.25
Inc 5/5/1 SMA 9150	8.70	5.00	9.92	8.70	6.02

TABLE C.3.2.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	3.51	0.00	3.71	3.51	3.57
Pol 6/2/1 SMA 9250	17.44	10.00	21.73	17.14	28.79
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	3.00	32.29	1.17	3.02	1.14
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	3.01	0.00	1.17	3.04	1.14
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	6.16	0.00	8.22	6.12	10.18
Inc 6/2/0 SMA 8050	3.22	0.00	1.95	3.36	0.00
Lang-Meyer SMA 8050 - v1	20.77	0.00	27.37	20.46	37.35
Lang-Meyer SMA 8050 - v2	20.76	91.67	1.25	21.00	0.00
Inc 5/5/1 SMA 9150	58.01	30.00	46.16	58.03	25.13

C.3.3 System availability of 90 percent, no terrain, two-way latency.—Figure C.3.3.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode without terrain information. For figure C.3.3.1, regions in black represent 215 min of latency. Table C.3.3.1 tabulates the weighted system latency for figure C.3.3.1. Table C.3.3.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

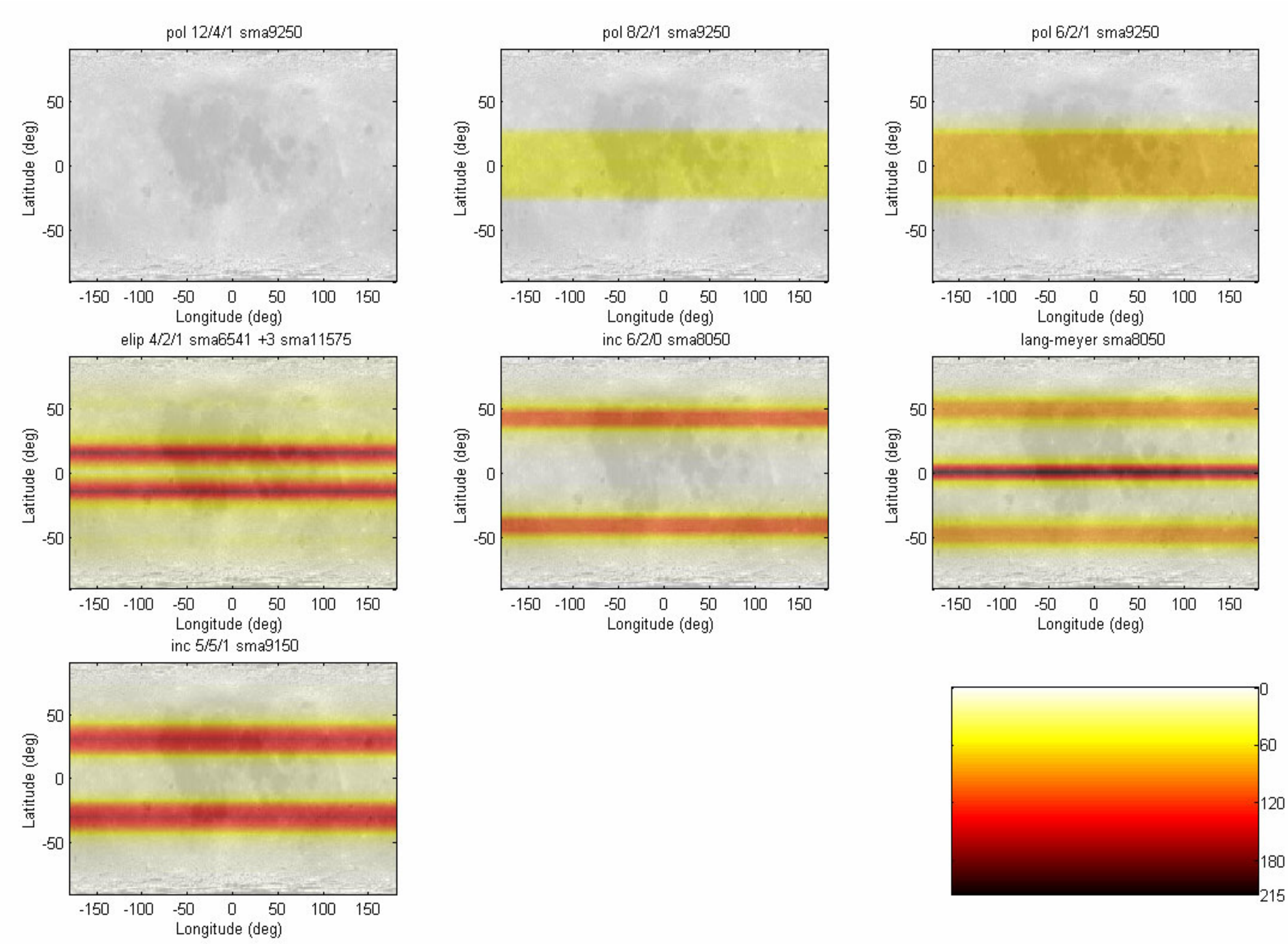

Figure C.3.3.1.—Lunar system latency results.

TABLE C.3.3.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	20.59	0.00	27.33	20.59	36.98
Pol 6/2/1 SMA 9250	36.39	0.00	48.30	36.39	63.57
Elip 4/2/1 SMA 6541 + 3 SMA 11575	58.98	10.00	71.91	59.03	88.96
Inc 6/2/0 SMA 8050	34.32	5.00	38.98	34.35	13.41
Lang-Meyer SMA 8050	48.96	5.00	52.42	48.90	47.49
Inc 5/5/1 SMA 9150	56.79	5.00	71.91	56.79	70.93

TABLE C.3.3.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	14.55	10.00	17.57	14.29	21.69
Pol 6/2/1 SMA 9250	22.48	30.00	19.25	22.15	19.16
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	14.32	33.75	12.19	14.27	14.43
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	14.26	0.00	12.21	14.10	14.54
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	24.85	0.00	32.61	24.81	35.82
Inc 6/2/0 SMA 8050	21.46	0.00	26.19	21.81	23.91
Lang-Meyer SMA 8050 - v1	34.49	0.00	45.53	34.00	51.44
Lang-Meyer SMA 8050 - v2	23.11	91.67	7.70	23.27	5.06
Inc 5/5/1 SMA 9150	72.75	30.00	65.43	72.57	58.96

***C.3.4 System availability of 90 percent, good terrain, two-way latency*.**—Figure C.3.4.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode with terrain information. For figure C.3.4.1, regions in black represent 215 min of latency. Table C.3.4.1 tabulates the weighted system latency for figure C.3.4.1. Table C.3.4.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

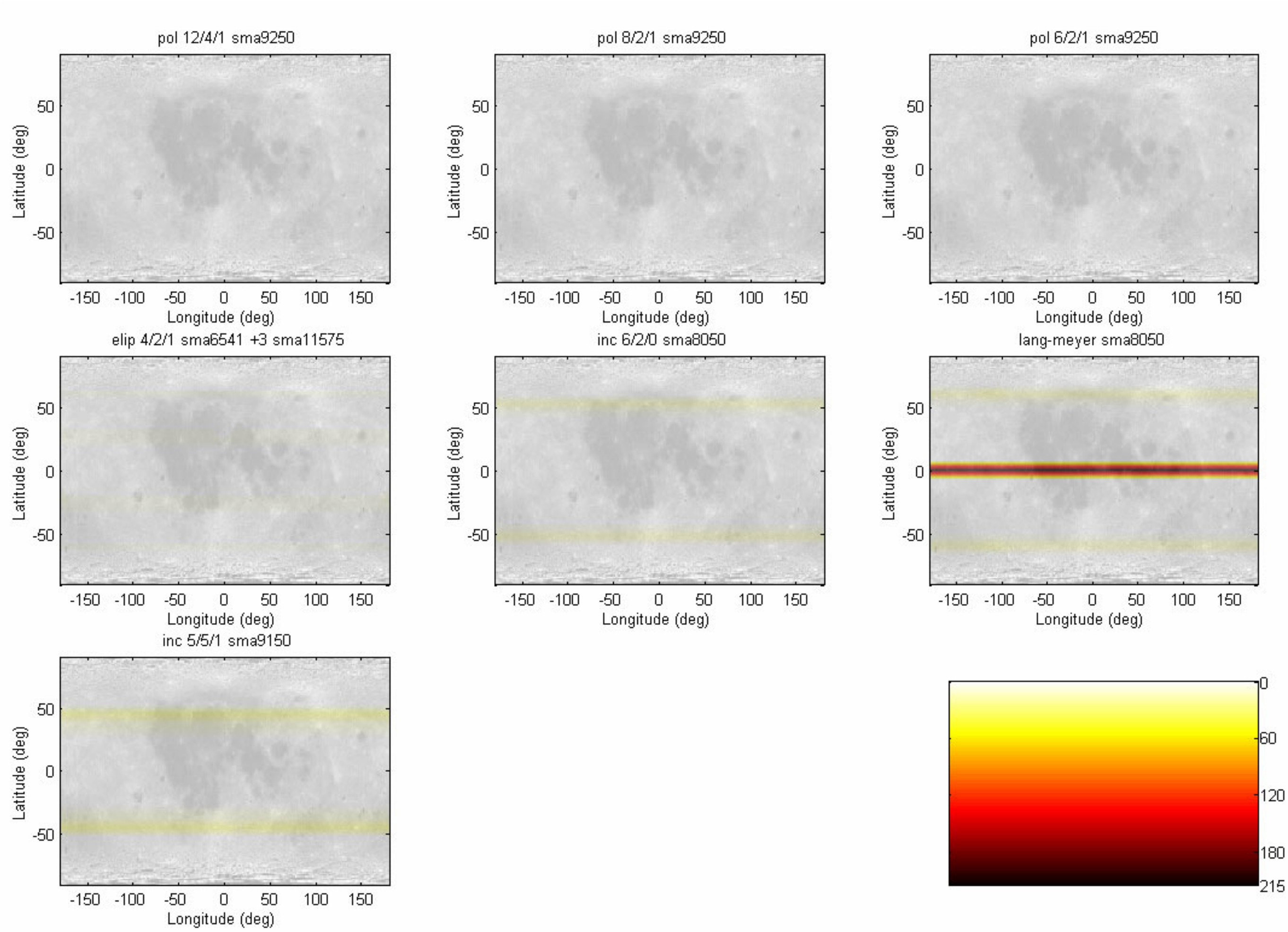

Figure C.3.4.1.—Lunar system latency results.

TABLE C.3.4.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 6/2/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Elip 4/2/1 SMA 6541 + 3 SMA 11575	1.50	0.00	1.53	1.53	2.01
Inc 6/2/0 SMA 8050	1.66	0.00	0.62	1.66	0.00
Lang-Meyer SMA 8050	15.23	0.00	18.40	15.21	24.84
Inc 5/5/1 SMA 9150	3.91	0.00	5.19	3.90	1.02

TABLE C.3.4.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	1.18	0.00	1.59	1.15	2.21
Pol 6/2/1 SMA 9250	13.30	0.00	18.03	12.96	24.18
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	2.04	32.08	0.43	1.99	0.65
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	2.08	0.00	0.43	2.10	0.64
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	3.82	0.00	5.09	3.79	7.16
Inc 6/2/0 SMA 8050	2.30	0.00	1.86	2.40	0.31
Lang-Meyer SMA 8050 - v1	19.82	0.00	26.50	19.49	34.36
Lang-Meyer SMA 8050 - v2	18.42	86.46	1.41	18.63	0.00
Inc 5/5/1 SMA 9150	51.59	25.00	39.37	51.49	21.14

C.3.5 System availability of 99 percent, no terrain, one-way latency.—Figure C.3.5.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode without terrain information. For figure C.3.5.1, regions in black represent 380 min of latency. Table C.3.5.1 tabulates the weighted system latency for figure C.3.5.1. Table C.3.5.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

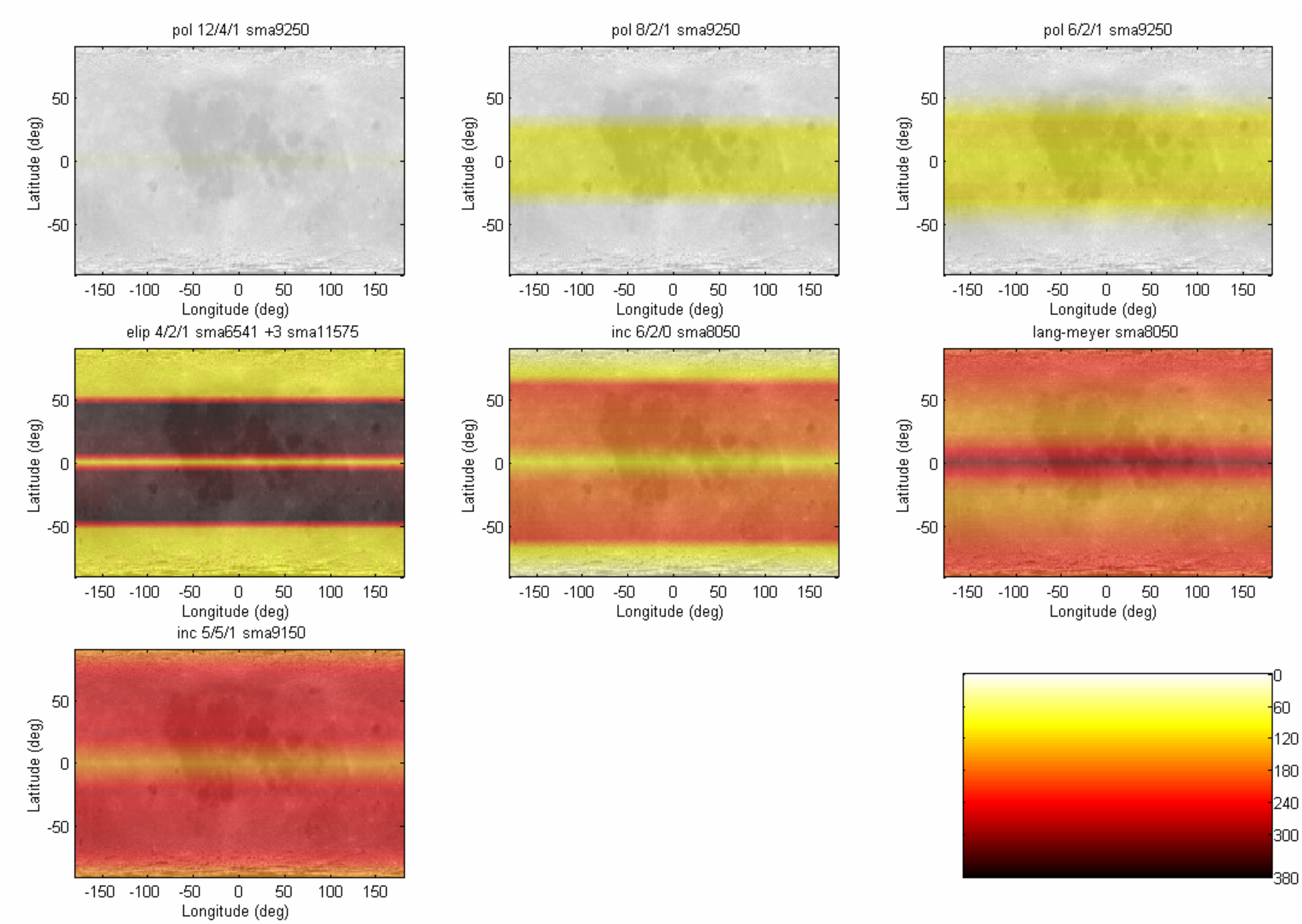

Figure C.3.5.1.—Lunar system latency results.

TABLE C.3.5.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	2.27	0.00	3.01	2.27	4.07
Pol 8/2/1 SMA 9250	46.24	5.00	59.73	46.24	79.07
Pol 6/2/1 SMA 9250	71.11	5.00	92.26	71.07	105.35
Elip 4/2/1 SMA 6541 + 3 SMA 11575	280.59	103.13	338.03	280.25	325.25
Inc 6/2/0 SMA 8050	172.67	48.75	175.73	172.68	168.34
Lang-Meyer SMA 8050	194.61	225.00	191.61	194.76	202.02
Inc 5/5/1 SMA 9150	233.39	195.00	227.91	233.41	219.42

TABLE C.3.5.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	33.24	0.00	44.40	33.00	59.99
Pol 8/2/1 SMA 9250	140.43	33.96	151.00	140.37	158.93
Pol 6/2/1 SMA 9250	265.05	130.00	294.96	264.99	337.16
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	40.74	42.08	16.90	40.45	23.06
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	40.83	86.25	16.70	40.49	22.24
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	280.08	6.87	344.22	281.74	348.35
Inc 6/2/0 SMA 8050	200.51	206.04	204.00	200.79	196.24
Lang-Meyer SMA 8050 - v1	78.47	0.00	102.53	78.07	114.57
Lang-Meyer SMA 8050 - v2	215.26	138.75	215.24	215.42	204.24
Inc 5/5/1 SMA 9150	256.85	223.33	253.79	257.24	223.84

C.3.6 System availability of 99 percent, good terrain, one-way latency.—Figure C.3.6.1 shows the system latency results for the seven lunar constellations when the system is operating in one-way mode with terrain information. For figure C.3.6.1, regions in black represent 305 min of latency. Table C.3.6.1 tabulates the weighted system latency for figure C.3.6.1. Table C.3.6.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

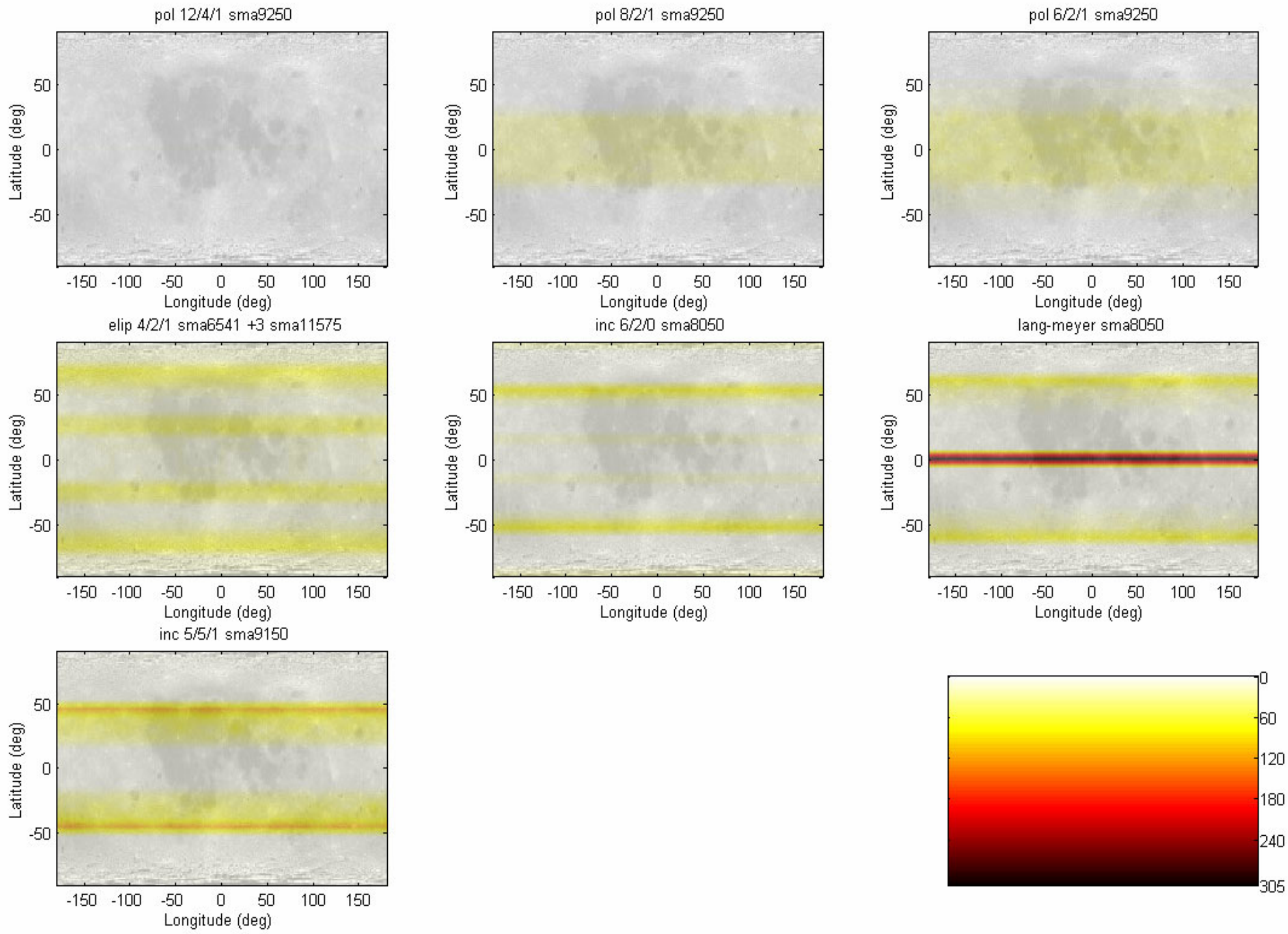

Figure C.3.6.1.—Lunar system latency results.

TABLE C.3.6.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.33	0.00	0.45	0.33	0.59
Pol 8/2/1 SMA 9250	12.39	0.00	16.46	12.37	22.30
Pol 6/2/1 SMA 9250	19.71	0.00	25.57	19.77	30.87
Elip 4/2/1 SMA 6541 + 3 SMA 11575	27.84	15.00	24.22	27.76	28.99
Inc 6/2/0 SMA 8050	14.75	10.00	9.96	14.73	8.41
Lang-Meyer SMA 8050	33.40	5.00	33.59	33.35	40.32
Inc 5/5/1 SMA 9150	29.97	5.00	37.61	29.97	21.43

TABLE C.3.6.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	2.20	0.00	2.89	2.21	3.98
Pol 8/2/1 SMA 9250	58.42	10.00	75.06	58.13	98.52
Pol 6/2/1 SMA 9250	164.72	35.42	213.32	164.20	277.50
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	21.29	90.00	16.44	21.33	9.43
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	21.52	0.00	16.68	21.59	10.11
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	318.48	0.00	418.30	317.95	400.88
Inc 6/2/0 SMA 8050	225.80	25.00	239.79	226.65	221.50
Lang-Meyer SMA 8050 - v1	97.64	0.00	128.04	97.53	152.41
Lang-Meyer SMA 8050 - v2	152.11	214.79	118.91	152.71	96.85
Inc 5/5/1 SMA 9150	280.97	175.00	271.51	280.97	249.94

C.3.7 System availability of 99 percent, no terrain, two-way latency.—Figure C.3.7.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode without terrain information. For figure C.3.7.1, regions in black represent 320 min of latency. Table C.3.7.1 tabulates the weighted system latency for figure C.3.7.1. Table C.3.7.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

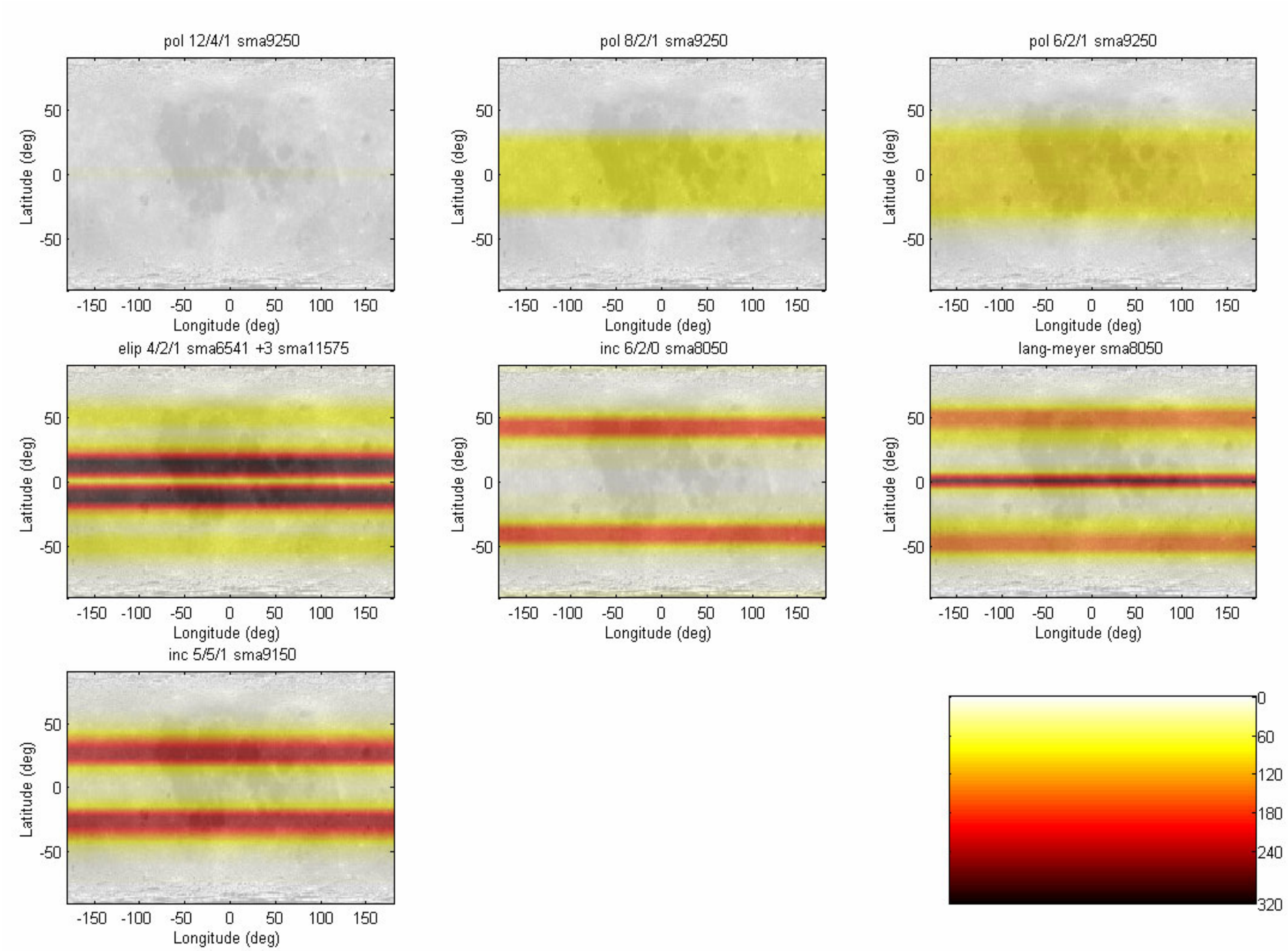

Figure C.3.7.1.—Lunar system latency results.

TABLE C.3.7.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.98	0.00	1.30	0.98	1.77
Pol 8/2/1 SMA 9250	42.22	0.00	56.03	42.22	75.82
Pol 6/2/1 SMA 9250	59.11	0.00	77.45	59.05	92.94
Elip 4/2/1 SMA 6541 + 3 SMA 11575	127.62	10.00	155.48	127.48	191.06
Inc 6/2/0 SMA 8050	57.20	10.00	66.67	57.23	26.10
Lang-Meyer SMA 8050	80.68	5.00	85.26	80.74	72.22
Inc 5/5/1 SMA 9150	96.16	5.00	123.29	96.20	132.76

TABLE C.3.7.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	9.01	0.00	12.02	8.97	16.09
Pol 8/2/1 SMA 9250	85.15	23.13	91.04	84.69	99.07
Pol 6/2/1 SMA 9250	185.74	80.00	210.39	185.41	261.49
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	24.72	95.00	16.95	24.73	12.46
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	24.56	0.00	16.84	24.41	12.55
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	305.28	0.00	404.00	305.18	380.82
Inc 6/2/0 SMA 8050	214.45	25.00	216.05	215.09	214.13
Lang-Meyer SMA 8050 - v1	115.69	0.00	153.48	115.44	181.34
Lang-Meyer SMA 8050 - v2	118.43	214.79	84.88	119.11	88.54
Inc 5/5/1 SMA 9150	259.49	175.00	243.11	259.43	206.18

***C.3.8 System availability of 99 percent, good terrain, two-way latency*.**—Figure C.3.8.1 shows the system latency results for the seven lunar constellations when the system is operating in two-way mode with terrain information. For figure C.3.8.1, regions in black represent 305 min of latency. Table C.3.8.1 tabulates the weighted system latency for figure C.3.8.1. Table C.3.8.2 tabulates the increases in system latency that occurred as a result of losing a single satellite (derived from the failure system latency analysis).

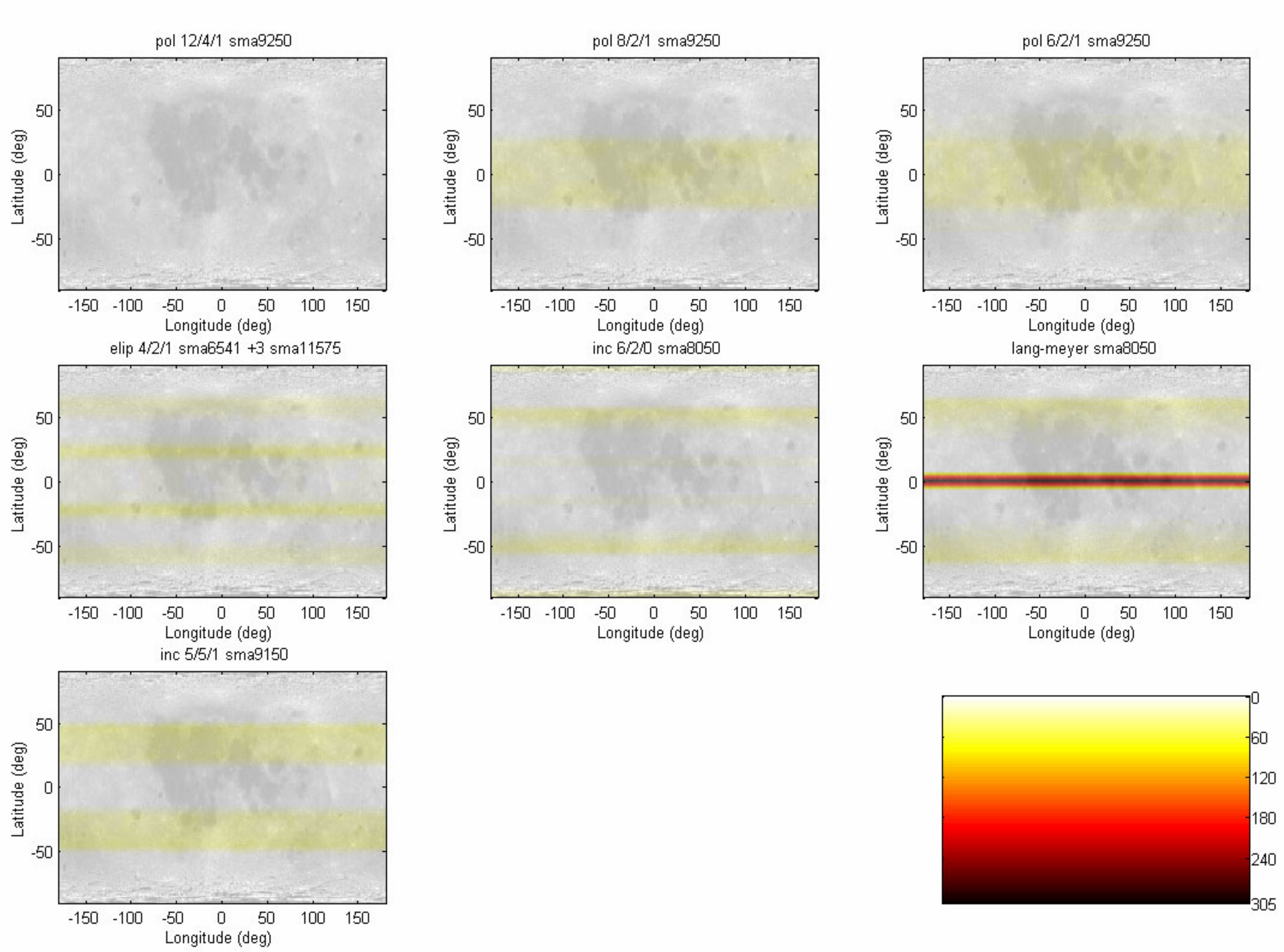

Figure C.3.8.1.—Lunar system latency results.

TABLE C.3.8.1.—WEIGHTED LUNAR SYSTEM LATENCY RESULTS

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.00	0.00	0.00	0.00	0.00
Pol 8/2/1 SMA 9250	10.70	0.00	14.30	10.62	18.93
Pol 6/2/1 SMA 9250	13.35	0.00	17.59	13.46	21.83
Elip 4/2/1 SMA 6541 + 3 SMA 11575	10.76	0.00	10.67	10.76	13.99
Inc 6/2/0 SMA 8050	6.10	4.58	4.55	6.06	2.27
Lang-Meyer SMA 8050	26.55	0.00	30.15	26.56	36.31
Inc 5/5/1 SMA 9150	13.70	0.00	18.20	13.68	12.94

TABLE C.3.8.2.—WEIGHTED LUNAR SYSTEM LATENCY INCREASES FROM FAILURE MODE SYSTEM LATENCY

Constellation	Regions on face of the Moon				
	Global	South pole	Front equatorial	Backside	Apollo
Pol 12/4/1 SMA 9250	0.31	0.00	0.40	0.33	0.59
Pol 8/2/1 SMA 9250	52.32	5.00	68.49	52.15	91.96
Pol 6/2/1 SMA 9250	160.24	15.42	209.37	159.82	274.32
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v1	22.59	95.00	16.47	22.56	9.26
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v2	22.48	0.00	15.97	22.72	8.98
Elip 4/2/1 SMA 6541 + 3 SMA 11575 - v3	318.47	0.00	419.68	317.84	402.78
Inc 6/2/0 SMA 8050	224.68	21.25	235.37	225.47	217.75
Lang-Meyer SMA 8050 - v1	92.52	0.00	121.94	92.38	146.76
Lang-Meyer SMA 8050 - v2	149.81	210.00	113.39	150.37	92.03
Inc 5/5/1 SMA 9150	286.54	170.00	280.00	286.52	247.61

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
The NASA Vision for Space Exploration is focused on the return of astronauts to the Moon. Although navigation systems have already been proven in the Apollo missions to the Moon, the current exploration campaign will involve more extensive and extended missions requiring new concepts for lunar navigation. In contrast to Apollo missions, which were limited to the near-side equatorial region of the Moon, those under the Exploration Systems Initiative will require navigation on the Moon's limb and far side. Since these regions have poor Earth visibility, a navigation system comprised solely of Earth-based tracking stations will not provide adequate navigation solutions in these areas. In this report, a dilution-of-precision (DoP)-based analysis of the performance of a network of Moon orbiting satellites is provided. This analysis extends a previous analysis of a lunar network (LN) of navigation satellites by providing an assessment of the capability associated with a variety of assumptions. These assumptions pertain to the minimum surface user elevation angle and a total single satellite failure in the lunar network. The assessment is accomplished by making appropriately formed estimates of DoP. Different adaptations of DoP, such as geometric DoP and positional DoP (GDoP and PDoP), are associated with a different set of assumptions regarding augmentations to the navigation receiver or transceiver.

15. SUBJECT TERMS
Moon; Navigation; Surface navigation; Doppler navigation; Radio navigation; Satellite navigation systems; Positioning; Satellite constellations

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