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SATCOP MISSION PLANNING SOFTWARE PACKAGE

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New laser ranging capabilities, additional satellites, and changing priorities are making it more difficult to determine the most efficient method of operations for NASA's CDSLR Network. A software package called SATCOP (Satellite Ranging Coordination Programs) has been developed to assist in mission support and planning operations. Its uses range from planning daily station operations to conducting pre-launch satellite visibility studies. SATCOP provides a listing and graphics output of satellite visibility for a given occupation site for any time period. SATCOP may also be used to determine the optimum ranging scenario for a station, taking into account satellite ranging priorities and station operational requirements. Finally, SATCOP may be used to illustrate simultaneous satellite visibility for multiple stations.

Introduction

As the CDSLR Network grows into the 1990's it is undergoing many changes in both its capabilities and requirements. On the one hand great progress has been made in terms of increasing the SLR systems' performance. Upgrades to the onsite computer and improved laser ranging hardware have greatly increased the number of satellite passes which can be acquired during an operating shift by reducing the amount of time needed for operations other than actual ranging. On the other hand, more requirements have been placed on the systems. Many more satellites have become available, with more scheduled for launch, thus increasing the likelihood of simultaneous satellite visibility. In addition, the possible scenarios required for ranging these many satellites are changing frequently, with conflicting priorities and needs.

It became apparent that some tools needed to be developed to assist the planners in determining Network ranging priorities. Such tools have been developed at Bendix under the direction of NASA's Dynamics of the Solid Earth Project (DOSE) for both long range planning and routine operations to maximize the amount of data collected. This paper will review some of these tools and describe their uses.

The SATCOP software package has several parts which are used for both routine operations and pre-launch scheduling. The use of such software helps determine pre-mission requirements such as ground track determination, forecasted station performance, predictions of optimum system locations, and predicted satellite visibility. SATCOP also produces graphs of ground tracks of acquired passes; determines availability of simultaneous ranging opportunities; schedules operating hours for maximum visibility; and produces automated single station scheduling for daily station activities.

Figure 1 is a time plot of satellite visibility for a given station. This figure demonstrates that even with just 6 satellites considered the opportunities for laser ranging are abundant. Such plots, and others like it, are used for operational scheduling of station activities and for the determination of operational requirements for future missions or locations. Typically such a plot is done for a 7 day period, but the number of satellites and number of days is user determined. The plot consists of a time scale in hours GMT across the top, and a day scale down the left. A subscale of each day is present, dividing each day into a line for each satellite. For each satellite, a two letter satellite identifier indicates the horizontal line across which the satellite could be visible (refer to Figure 8 to identify the satellite associated with each two letter identifier). Across the plot a solid line indicates when a satellite is visible, and a total number of minutes for that day is printed on the right. On the last day of the plot a column on the right also indicates the total number of minutes visible during the time period of the plot.

Figure 2 illustrates the number of possible sightings of two satellites over a four day period at 5 locations. Such graphs are used when extended time periods are considered, and can be used to compare satellite visibility at several stations simultaneously. Such graphs are useful for determining the best of several possible station locations and the expected visibility at a given location, and can include several satellites. Often it is also desired to know the number of possible simultaneous sightings of a satellite for several locations. Figures 3 and 4 demonstrate the tools used for determining this number. Figure 3 is a matrix showing the number of mutual sightings possible at several locations. The number of such sightings for a given pair of stations is found by cross indexing between the two desired stations to find the result within the matrix; as an example for MOBLAS 4 (7110) and MOBLAS 8 (7109) the number of such sightings is found to be 130. Figure 4 is a listing of all possible subsets of the desired stations which can range, along with the times of mutual availability. The user can determine the minimum number of stations desired for simultaneous ranging, and the time period for consideration.

The SATCOP software package has been developed to provide support for other purposes as well. Figure 5 is a plot which shows the distribution of acquired LAGEOS passes reported as quicklook data for the time period May 2 to May 14, 1992. This type of plot allows the user to quickly determine the geographic distribution of data reported during the indicated time period. Figure 6 is used to compare sightings for two or more stations over a 24 hour period, and is read similarly to Figure 1. Such a graph is convenient for quickly determining the opportunities for coordinated activities between two or more locations with one or more satellites.

A major use for the SATCOP package is single station scheduling for daily activities. The purpose of such scheduling is to assist the station crew in conducting laser operations by considering as many of the requirements and opportunities presented to the station as possible, and then producing a schedule which is a possible 'optimum' solution for the day's activities.

To perform such scheduling many parameters are considered. A major requirement is to resolve ranging opportunities when two or more satellites are visible simultaneously. SATCOP considers satellite priority, ranging limitations such as a maximum time limit on a satellite pass, and day or night ranging restrictions. If two satellites of the same priority are available then the software ensures that ranging is as evenly distributed between the two during the day as possible, based on available minutes of data. Activities which may exclude laser activities are taken into account, such as data preprossessing and calibration time. If the system has the multi-satellite calibration capability then the software determines a best sequence for calibration and ranging.

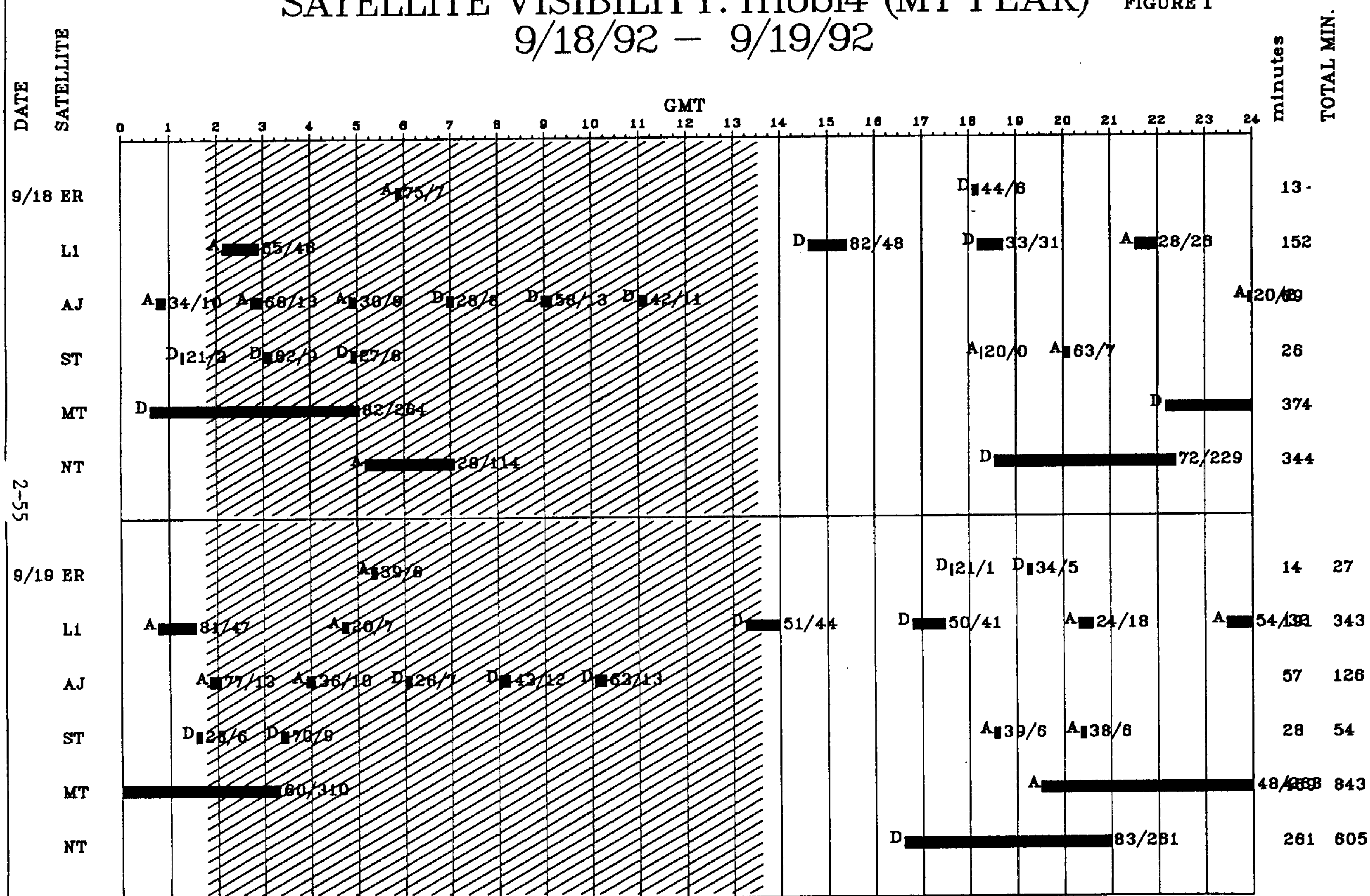
As an example a schedule generated for MOBLAS 4 at Monument Peak will be considered, using the time period covered by Figure 1. Some of the parameters used for generating the schedule are illustrated in Figures 7 and 8. As an aid to readability only two days will be scheduled, but normally a regular workweek is considered. The hours of operation were determined previously using other methods described earlier. From this information the schedule sent to the station is graphically shown in Figure 9. Looking at the plot for each day there is a line corresponding to each satellite plus an additional line showing laser calibration, denoted by 'C1'. Since this system is using the multi-satellite calibration capability data may be acquired on several satellites between calibrations. Also, since the overhead time has been greatly reduced by this, and other, upgrades true interleaving of passes is possible when a high priority short pass occurs at the same time as a low priority long pass. The thick line represents the time that the station is actually ranging (or calibrating), while the thin line represents the time the satellite is actually visible (the thick line corresponding to the ranging of a given pass is located above the thin line).

Conclusion

In the future the requirements for SLR activities will only become greater. New satellites, new ranging scenarios, and new station abilities will require changes to be made to the methods used to schedule operations. Recent examples are the ETALON campaign and the multi-satellite upgrade. Of course, many possible parameters have yet to be considered. Obviously it is impossible to account for poor weather conditions deterring laser activities on a given day, but plans are being considered to include long term weather effects as a statistical modification of the predicted station performance. And it would be similarly difficult to account for system down time due to component failure. But the use of this package, and its continued improvement, has allowed Bendix to more efficiently coordinate the NASA CDSLR network activities.

SATELLITE VISIBILITY: mobl4 (MT PEAK)
9/18/92 – 9/19/92

FIGURE 1



total time for all satellites is 1998

date created: 9/15/92

CDSLR/OAS
BUCEY

letter on curve indicates ascending/descending

SHADED SECTION IS NIGHT

NOTATION ON PASS IS MAXIMUM ELEVATION–
AND NUMBER OF MINUTES

PASSES BY STATION AND SATELLITE

FIGURE 2

	511 517 LAG	AJI	518 524 LAG	AJI	525 531 LAG	AJI	601 607 LAG	AJI		Totals LAG	AJI
7110	LAG	AJI	LAG	AJI	LAG	AJI	LAG	AJI		LAG	AJI
DAY	15	0	11	4	15	8	12	16			
TWILIGHT	2	0	4	2	1	3	1	2		137	161
NIGHT	18	40	19	35	19	28	20	23			
7090	LAG	AJI	LAG	AJI	LAG	AJI	LAG	AJI		LAG	AJI
DAY	15	9	15	16	15	19	12	23			
TWILIGHT	1	2	0	2	1	0	1	3		130	150
NIGHT	17	27	18	20	15	18	20	11			
7105	LAG	AJI	LAG	AJI	LAG	AJI	LAG	AJI		LAG	AJI
DAY	14	3	12	9	13	15	11	21			
TWILIGHT	2	2	2	2	1	2	1	3		127	138
NIGHT	16	30	18	23	18	18	19	10			
7109	LAG	AJI	LAG	AJI	LAG	AJI	LAG	AJI		LAG	AJI
DAY	14	0	11	1	15	6	12	14			
TWILIGHT	3	0	3	2	1	3	1	2		134	152
NIGHT	17	38	19	35	18	28	20	23			
7080	LAG	AJI	LAG	AJI	LAG	AJI	LAG	AJI		LAG	AJI
DAY	17	5	13	10	16	18	14	22			
TWILIGHT	3	3	3	2	1	2	1	3		159	205
NIGHT	20	43	24	39	23	32	24	26			

Mutual sightings of LAGEOS by any two stations FIGURE 3
for the period 92Ø511.Ø to 92Ø6Ø7.Ø

The upper diagonal is number of mutual trackings.
The lower diagonal is minutes of mutual trackings.

	7Ø8Ø	7Ø9Ø	71Ø5	71Ø9	711Ø	7112	7123	721Ø	7843	7939
7Ø8Ø	Ø	Ø	119	13Ø	133	Ø	52	81	Ø	14
7Ø9Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	113	Ø
71Ø5	3326	Ø	Ø	1Ø5	1Ø6	Ø	Ø	18	Ø	6Ø
71Ø9	51Ø9	Ø	1997	Ø	13Ø	Ø	45	77	Ø	Ø
711Ø	4719	Ø	1847	4337	Ø	Ø	45	74	Ø	Ø
7112	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø
7123	1Ø57	Ø	Ø	42Ø	521	Ø	Ø	7Ø	38	Ø
721Ø	2369	Ø	74	19Ø8	1788	Ø	1431	Ø	14	Ø
7843	Ø	2783	Ø	Ø	Ø	Ø	668	54	Ø	Ø
7939	168	Ø	413	Ø	Ø	Ø	Ø	Ø	Ø	Ø

FIGURE 4

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these  4 stations can track on the sighting date 920511
during the common sighting time 00:20:10.00 to 00:34:43.00
7110 00:05:52.00 to 00:34:43.00  start az: 15. ang: 20.   end az:296. ang: 20.   max el: 31.
7109 00:01:34.00 to 00:39:16.00  start az: 27. ang: 20.   end az:278. ang: 20.   max el: 44.
7080 23:48:34.00 to 00:40:56.00  start az: 40. ang:  0.   end az:291. ang:  0.   max el: 24.
7210 00:20:10.00 to 01:02:15.00  start az: 10. ang: 20.   end az:243. ang: 20.   max el: 52.

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these  2 stations can track on the sighting date 920511
during the common sighting time 01:14:01.00 to 01:50:09.00
7843 01:01:28.00 to 01:50:09.00  start az: 31. ang: 20.   end az:207. ang: 20.   max el: 87.
7090 01:14:01.00 to 01:52:20.00  start az: 84. ang: 20.   end az:192. ang: 20.   max el: 43.

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these  4 stations can track on the sighting date 920511
during the common sighting time 03:23:43.00 to 03:43:45.00
7105 03:06:19.00 to 03:43:45.00  start az:125. ang: 30.   end az:337. ang: 30.   max el: 73.
7110 03:23:23.00 to 03:51:47.00  start az: 63. ang: 20.   end az:346. ang: 20.   max el: 31.
7109 03:23:43.00 to 03:58:34.00  start az: 69. ang: 20.   end az:331. ang: 20.   max el: 39.
7080 03:01:36.00 to 04:00:45.00  start az: 98. ang:  0.   end az:331. ang:  0.   max el: 36.

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these  5 stations can track on the sighting date 920511
during the common sighting time 06:59:19.00 to 07:06:41.00
7105 06:52:48.00 to 07:06:41.00  start az:239. ang: 30.   end az:283. ang: 30.   max el: 33.
7210 06:59:19.00 to 07:23:26.00  start az: 71. ang: 20.   end az: 13. ang: 20.   max el: 27.
7110 06:39:10.00 to 07:27:03.00  start az:146. ang: 20.   end az:334. ang: 20.   max el: 87.
7109 06:43:49.00 to 07:31:46.00  start az:145. ang: 20.   end az:333. ang: 20.   max el: 89.
7080 06:24:30.00 to 07:33:54.00  start az:158. ang:  0.   end az:336. ang:  0.   max el: 74.

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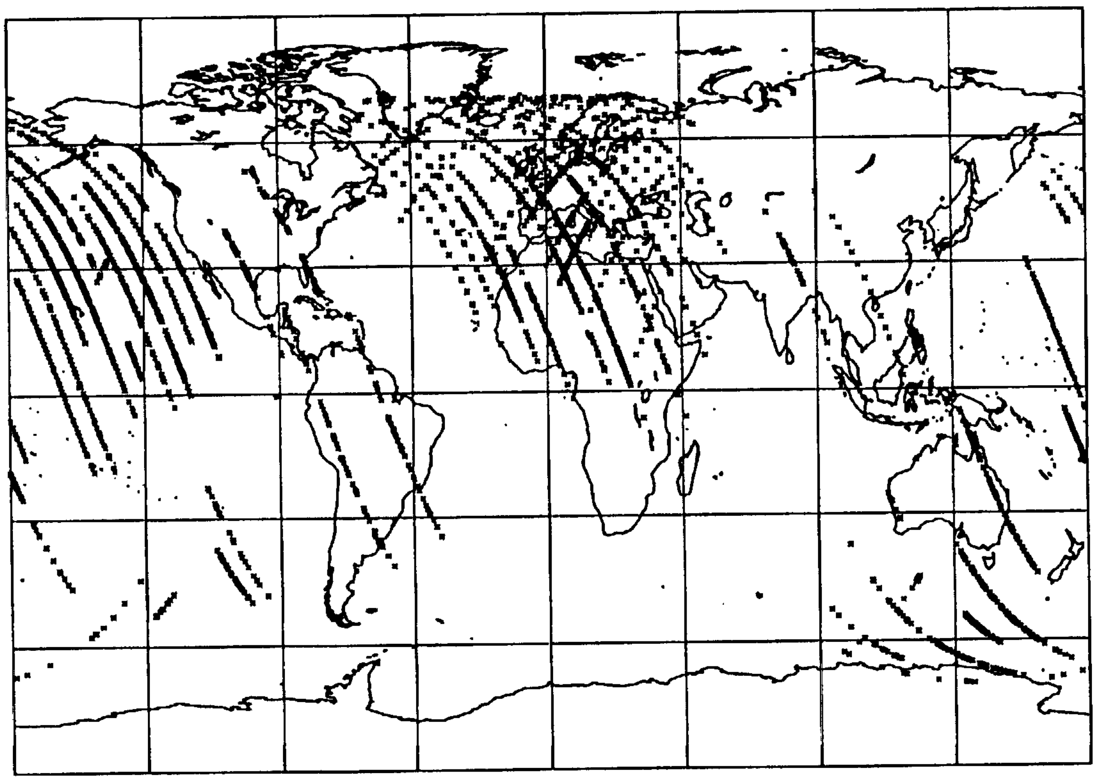
Figure 5

QUICK-LOOK ANALYSIS REPORT



AUG 1 - AUG 7 1992

ALLIED-SIGNAL AEROSPACE/BENDIX FIELD ENGINEERING CORP.   CDSLR/DSG/OAS

SATELLITE VISIBILITY: 92/ 9/14

FIGURE 6

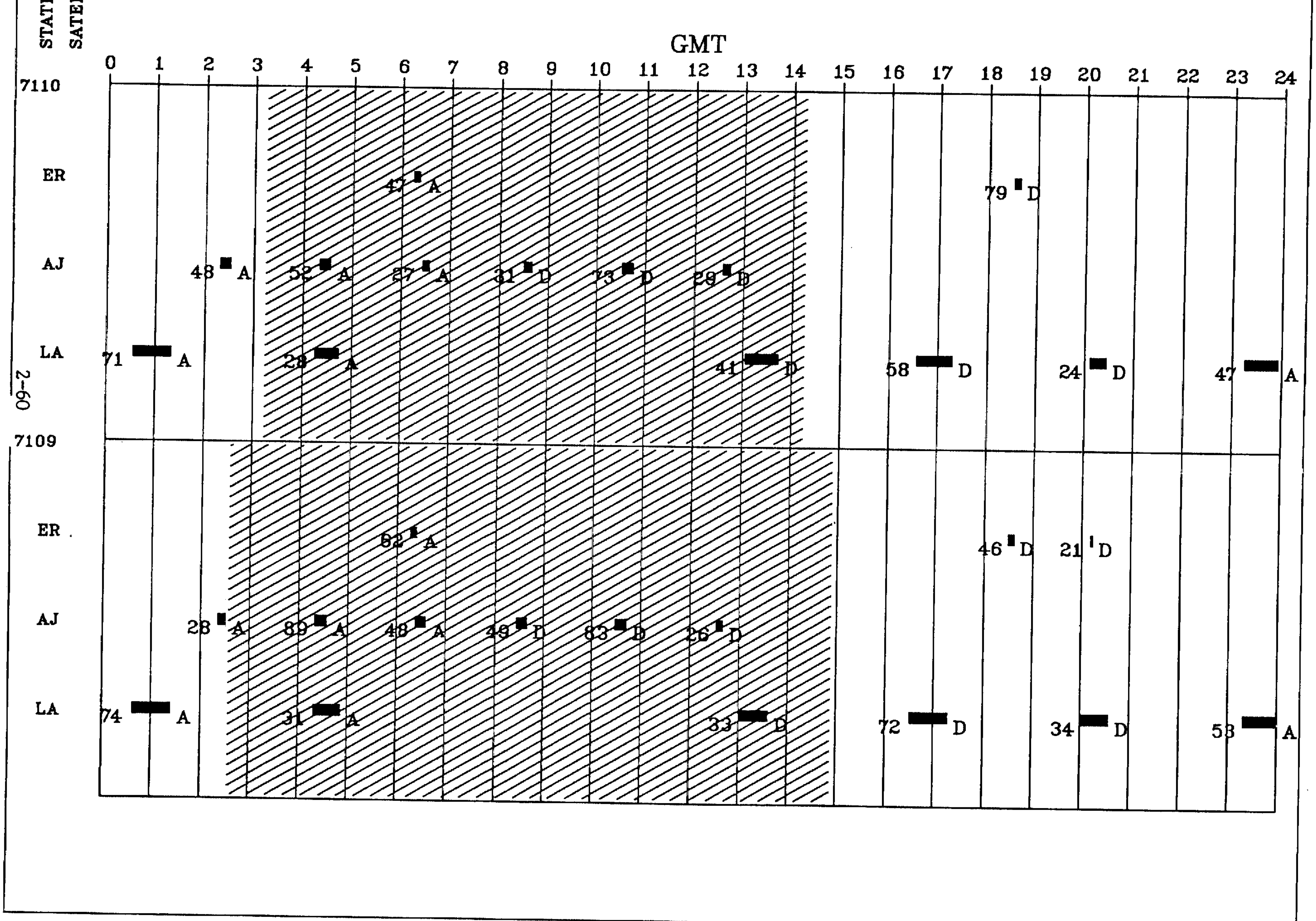


FIGURE 7

SYSTEM TRACKING PARAMETERS FOR MOBLAS 4 AT MT. PEAK.

1. MAY TRACK BOTH DAY AND NIGHT.
2. REQUIRES ABOUT 7 MINUTES FOR PRE/POST-PASS EXTERNAL CALIBRATION.
3. MINIMUM TRACKING ANGLE IS 20 DEG.
4. SYSTEM ABLE TO PROCESS ACQUIRED DATA IN PARALLEL WITH OTHER OPERATIONS.
5. SYSTEM USING MULTI-SATELLITE CALIBRATION CAPABILITY.
6. THE SATELLITE PRIORITIES, MINIMUM TRACK AND OTHER PARAMETERS ARE CHOSEN FOR DEMONSTRATION BUT MAY VARY WITH SATELLITE AND STATION.

FIGURE 8

SATCOP INPUT PARAMETERS

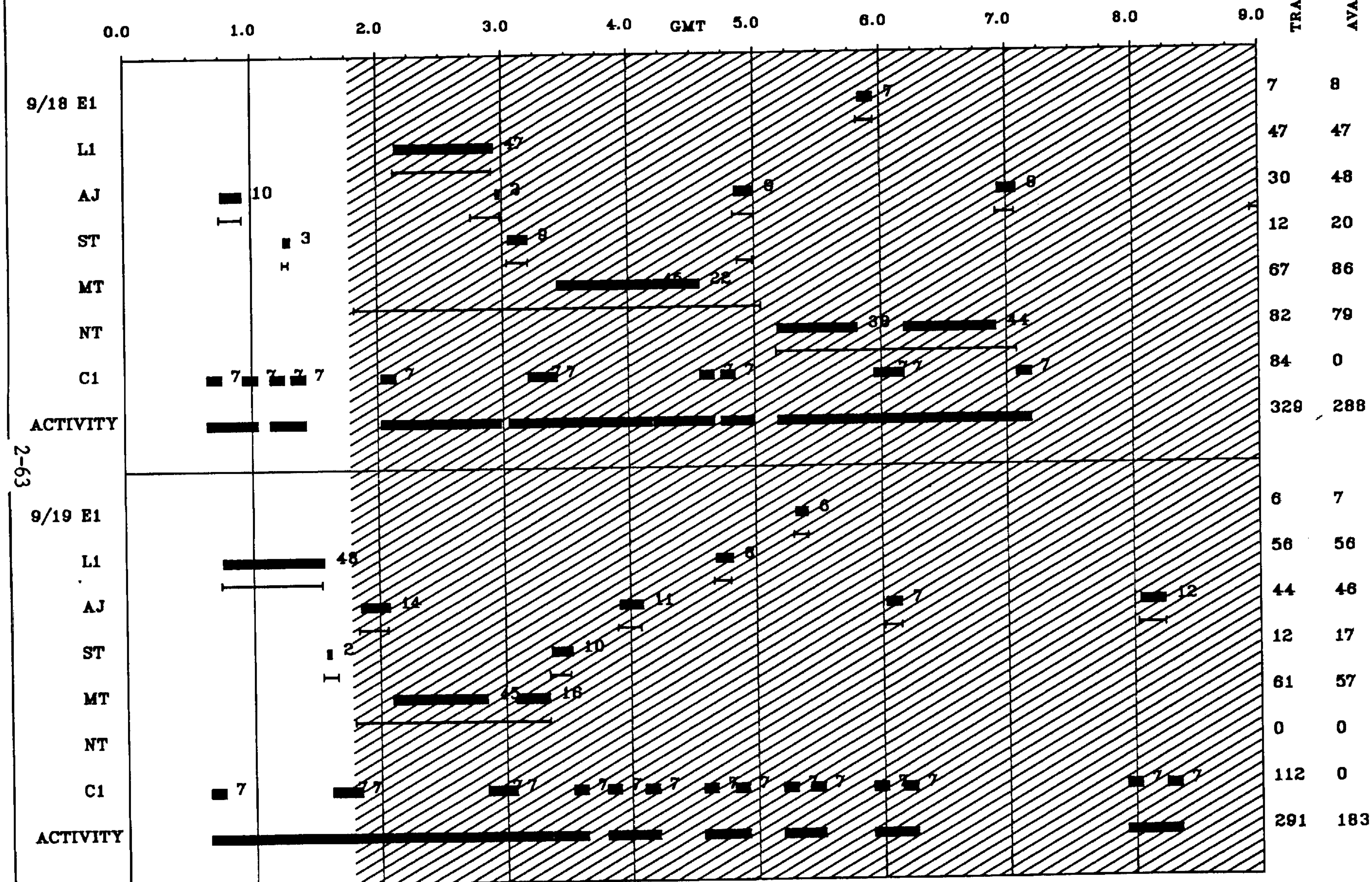
1. TRACKING PERIOD: SEP 18 - SEP 19, 1992.
2. STATION AVAILABILITY: 24 HOURS/DAY.
3. "WORK WEEK": 2 DAYS.

4. SATELLITE PRIORITIES:
   - 1: ERS-1 (E1 OR ER)
   - 2: LAGEOS (L1 OR LA)
   - 3: AJISAI (AJ)
   - 4: STARLETT (ST)
   - 5: ETALON 1 (MT)
   - 5: ETALON 2 (NT)

NOTE: ETALON TRACKING LIMITED TO 45 MINUTE SEGMENTS.

SATELLITE VISIBILITY: MOBL4 (7110) 9/18/92 – 9/19/92 SHIFT NUMBER 1

FIGURE 9



date created: 9/15/92

BFEC/CDSLR DSG Bucey Conklin

THICK SOLID CURVE IS ACTUAL TRACKING.
ATTACHED THIN CURVE IS PRE/POST CAL TIMES.
NOTATION ON PASS IS MINUTES OF PASS TRACKED.

SINGLE THIN LINE IS ACTUAL VISIBLE PASS.

SHADED SECTION IS NIGHT.

Laser Technology