Long-Term Analysis of the Corrective Maintenance Records of the ARM SGP CART

J. J. Teske
Aeromet Corporation
Tulsa, Oklahoma

J. C. Liljegren and D. L. Sisterson
Environmental Research Division
Argonne National Laboratory
Argonne, Illinois

Introduction

The primary responsibility of Southern Great Plains (SGP) Site Operations is to operate and maintain the Atmospheric Radiation Measurement (ARM) instruments at the SGP Cloud and Radiation Testbed (CART) facilities. Since 1992, SGP Site Operations has maintained detailed corrective maintenance records for the ARM SGP instruments as part of the SGP Operations and Maintenance Information System (OMIS). These records are available online at http://www.ops.sgp.arm.gov. We analyzed these records back to 1995. They reveal maintenance trends that vary by instrument type, location, and year. They provide valuable insights into the performance of the instruments and indicate areas where improvements would yield the greatest benefits.

Record-Keeping Procedures

New maintenance records, like the example in Figure 1, are completed electronically by SGP field technicians for each corrective maintenance action they perform. A corrective maintenance action can be as simple as cleaning an instrument window or dome after a routine inspection has revealed the necessity of such action, or it can be as complex as repairing an entire laser sub-system. Although not shown in Figure 1, the time required by the technician to effect the corrective action is also recorded.

To simplify the record-keeping effort for the technicians and to ensure consistency of the records (which is essential to their subsequent analysis) most fields are selected from a pre-determined list. The only text fields the technicians fill out are the problem description and the action performed. To ensure accuracy, new records are checked by the SGP Maintenance Department Head after the technicians return, and are reviewed by the SGP Site Operations Manager before being merged with the existing database, which was developed using Filemaker Pro software. To facilitate analysis of the data, the records were exported from Filemaker Pro and imported into Data Desk, a relational analysis software package.

ARM PROGRAM SGP CART SITE

OMIS

Corrective Maintenance Report

Instrument:	RAMAN LIDAR
Location:	Central Facility
Date/Time (GMT)	12/15/2000 2000
Technician:	Chris Martin
Maint. Type:	Unscheduled CM
Problem Fixed:	No
Suspected Cause:	HW Failure
Component:	Laser
Problem Description:	The Raman Lidar laser energy had fallen to around 200 mJ. The lamps were due to be replaced, but the energy seemed to drop off rather quickly the past couple of days.
Action Performed:	Inspection of the optics during lamp replacement found that the Pockells Cell was burned. The Pockells cell had just been installed by Continuum on 10/19 and should be under warranty. Scheduled a Continuum service call for 12/18. System off line until then.

Figure 1. An example of a corrective maintenance report in the SGP OMIS. These reports are available online at http://www.ops.sgp.arm.gov

Results

The bar chart in Figure 2 shows that the number of corrective maintenance actions increased as instrument deployments proceeded, then leveled off in 1997 once the SGP instrument complement stabilized. The SGP is composed of 26 extended facilities, 4 boundary facilities, 3 intermediate facilities, and the central facility. Within each facility class the instrumentation is very nearly identical. The chart in Figure 2 shows that the majority of the corrective maintenance actions were carried out for the extended facilities due to their comparatively greater numbers. However, the central facility, which has more complex and sophisticated instrument systems, also contributes significantly to the corrective maintenance burden.

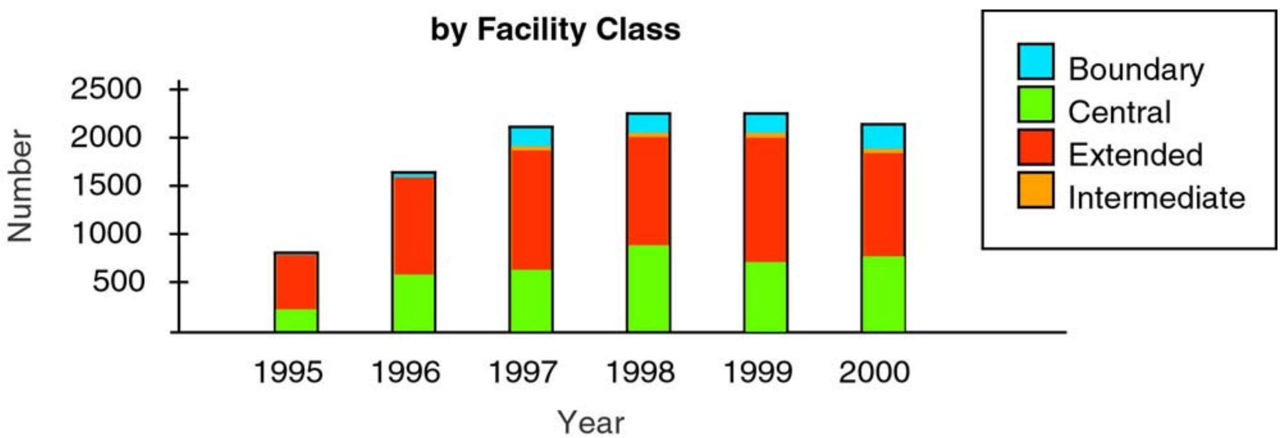


Figure 2. A chart illustrating the trend in corrective maintenance actions by facility type at the SGP since 1995.

In Figure 3 we present pie charts that illustrate the distributions of corrective maintenance actions for (a) all SGP instruments, (b) central facility instruments, (c) boundary facility instruments, and (d) extended facility instruments. Not all instruments are listed on the charts: any instrument that contributed less than 2 percent of the total maintenance actions for that facility type was consolidated into "Other." (Instrument names and acronyms are listed at http://www.arm.gov/docs/sites/sgp/sgp_instruments.html.) As Figure 2 also indicates, extended facility instruments dominate the corrective maintenance action distribution for all instruments due to their numbers. The only single-instrument categories that are significant at the 2 percent level are the raman lidar, whole sky imager, and aerosol observing system.

Figure 3b, which shows the distribution of corrective actions by instrument for the central facility, is dominated by the raman lidar. (The large "other" category shows that infrequent maintenance actions have a substantial impact on SGP operations.) The pie chart in Figure 4 presents the distribution of raman lidar maintenance by component. The numbers in parentheses indicate the average time spent (in minutes) for each component. For example, although the window needed cleaning about as often as the laser subsystem (including the optics) needed attention, the window only required 22 minutes on average, whereas the laser required over 2 hours on average. Consequently, improvements that reduce the need for laser-related maintenance are more beneficial. Such improvements are illustrated by the bar

Figure 3. Charts illustrating the distributions of corrective maintenance actions.

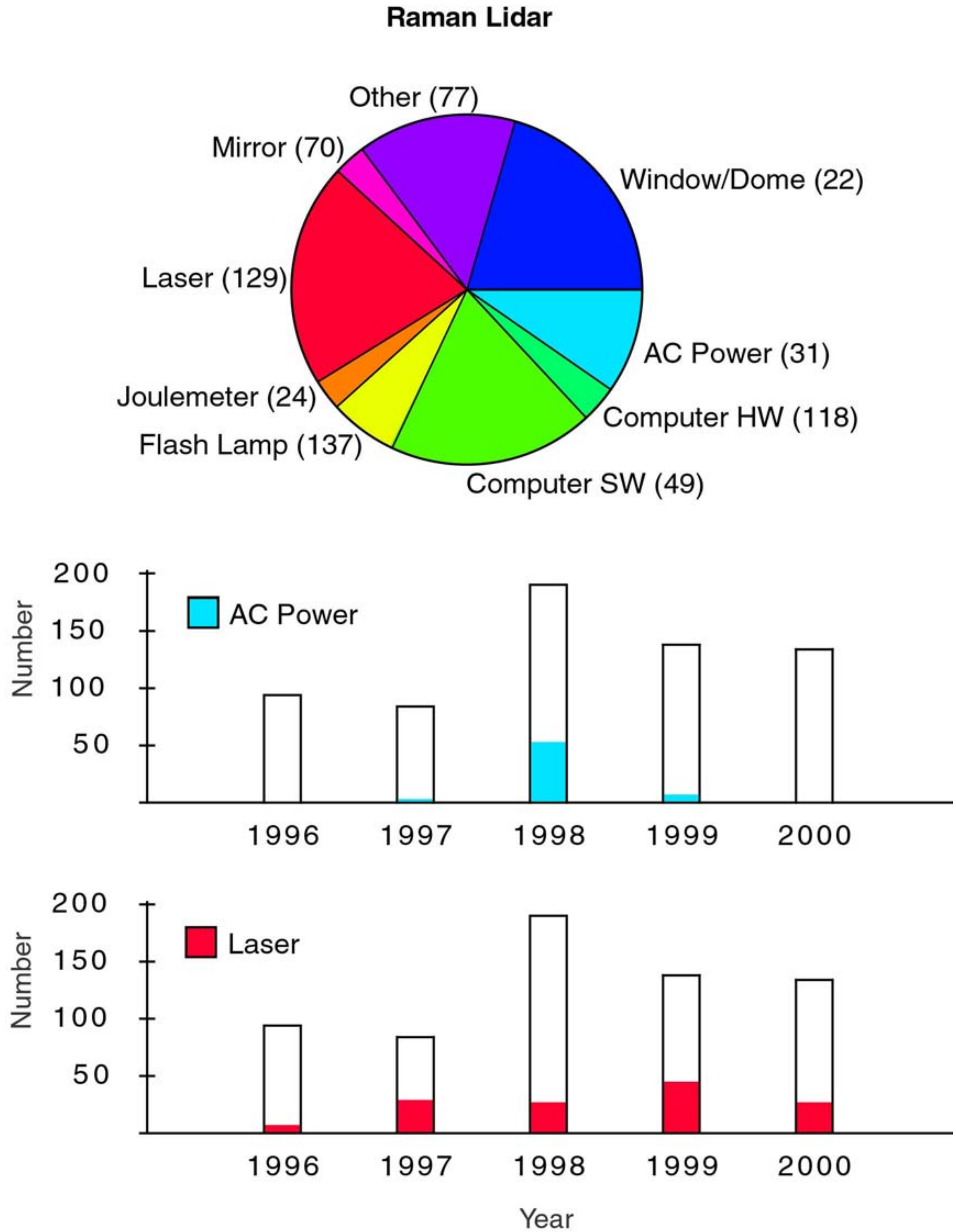


Figure 4. Charts illustrating the distribution of corrective maintenance action by component for the raman lidar, and trends in maintenance actions for specific raman lidar components.

charts in Figure 4. After a large uninterruptible power supply was installed on February 12, 1999, the incidence of power-related corrective maintenance actions were dramatically reduced. Installation of a large dehumidifier on November 16, 1999, significantly reduced the incidence of damage to the laser optics due to high relative humidity in the lidar shelter.

Figure 3c shows that the microwave radiometers have dominated the corrective maintenance actions for the boundary facilities since they were deployed in January 1994. However, the Atmospherically Emitted Radiation Interferometer (AERI) spectrometers, which were not deployed at the boundary facilities until December 1998, have required a steadily increasing number of corrective actions as the bar chart in Figure 5 indicates. Although recent problems with the interferometers arose, most of the problems have been associated with the OS/2-based software. Discussions with personnel at Bomem, Inc. and with the University of Wisconsin Space Science and Engineering Center were initiated to address these problems.

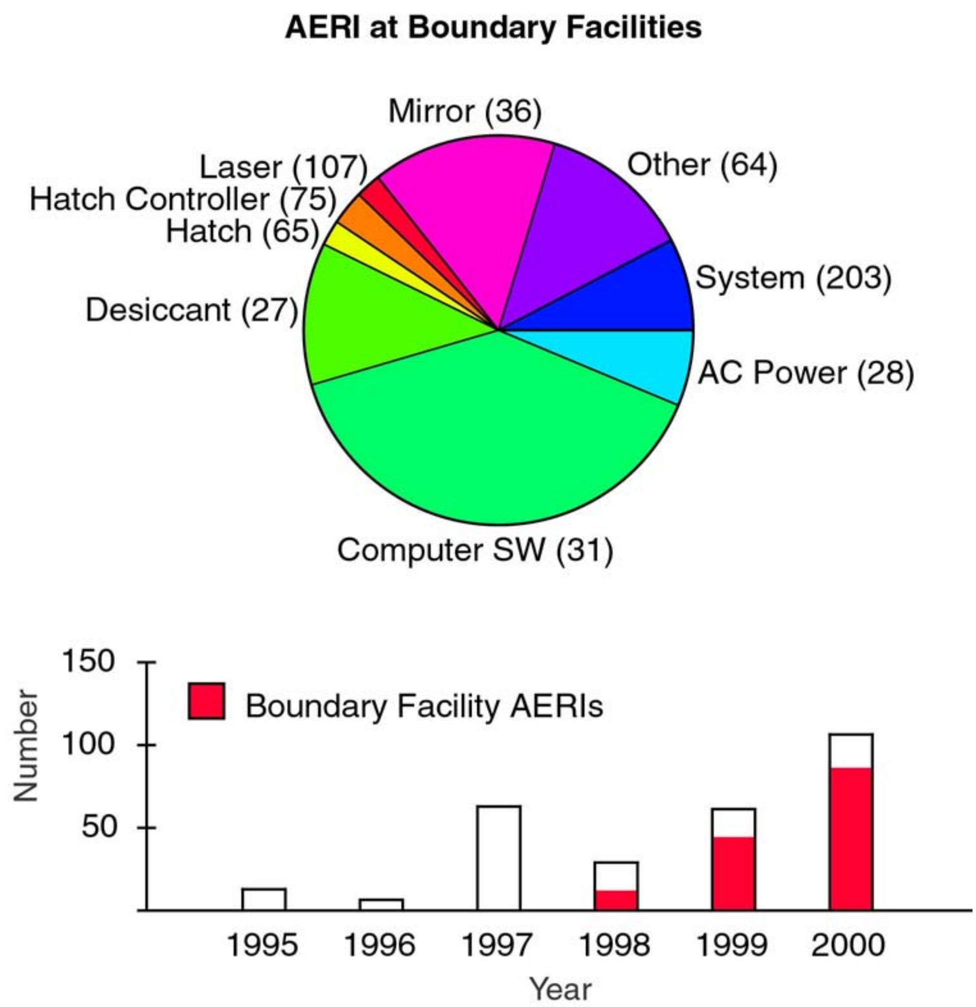
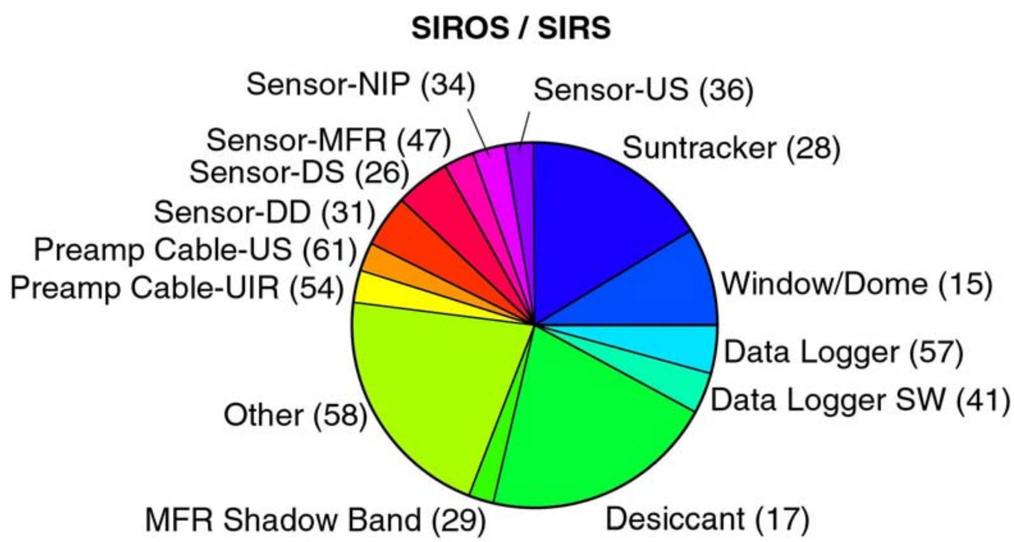


Figure 5. The distribution of corrective maintenance action and average time spent (in minutes) by component for the AERI spectrometers at the boundary facilities and the trend of increasing maintenance actions required.

Figure 3d shows that the solar and the infrared radiation station (SIRS) and its predecessor, the solar and infrared radiation observing system (SIROS), dominate the corrective actions at the extended facilities. The pie chart in Figure 6 illustrates that while the solar trackers required attention much more frequently than the data loggers, the much greater average time spent on data logger problems represented a significant maintenance issue at the extended facilities. The data loggers were replaced between September and November 1997 during the conversion from SIROS to SIRS. The reduction in corrective maintenance incidents required after the replacement of the data loggers is evident in the accompanying bar chart. Not evident in these charts is the improvement in data reliability associated with the new data loggers.



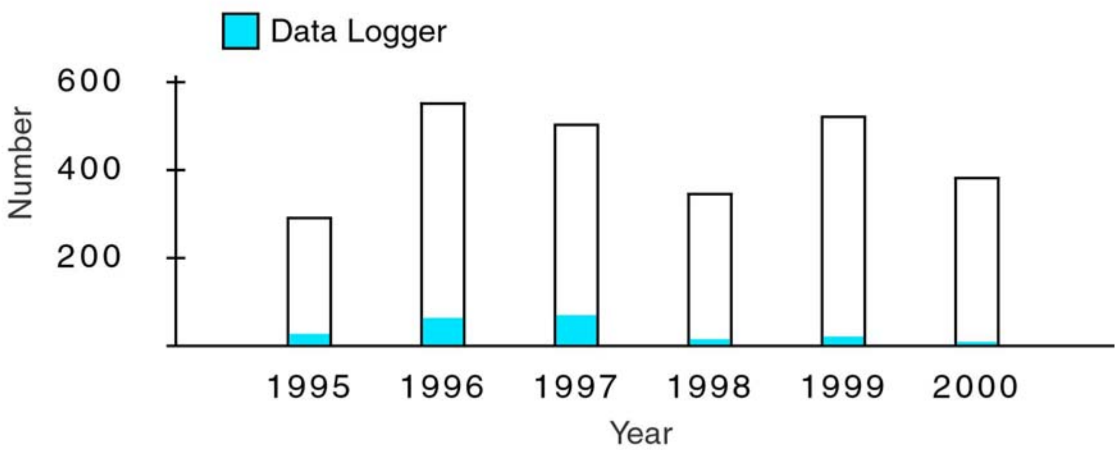


Figure 6. The distribution of corrective maintenance action and average time spent (in minutes) by component for the SIRS and its predecessor, the SIROS at the extended facilities. The reduction in corrective maintenance incidents required after the replacement of the data loggers in late 1997 is shown in the accompanying bar chart.

Future Work

Currently, the ARM Operations group is developing a cost metric for each of the instruments that combine the effort of corrective maintenance with the cost of repairs. This information can be used to determine the appropriate time to replace aging instrumentation in the field, not only at the SGP but also at the other CART sites.

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Corresponding Author

James C. Liljegren, liljegren@anl.gov, (630) 252-9540