Final Report on the Cost-Benefit Study for the SLF Meteorological Equipment

Prepared for:
NASA
Kennedy Space Center
Under Contract NAS10-11844

15 November 1996

Prepared By:
Applied Meteorology Unit

ENSCO, Inc.
445 Pineda Court
Melbourne, Florida 32940
(407) 853-8105
(407) 254-4122

Attributes and Acknowledgments:

NASA/KSC POC:
Dr. Frank Merceret, Chief, Applied Meteorology Unit/PH-B3

Applied Meteorology Unit (AMU):

Lou Rosati, Primary Author
Ed Harkins
Ann Yersavich

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

1. Introduction

1.1 Purpose of the Report

ENSCO was tasked to perform a cost-benefit study of possible options that would facilitate the certification and transfer of the meteorological equipment associated with towers 0511, 0512, and 0513 located at the Shuttle Landing Facility (SLF) to the Eastern Range (ER). The study was completed in two phases due to monetary and time constraints. Phase 1 was an initial high level assessment of four possible options concentrating primarily on eliminating options from further investigation that would not be cost or benefit effective. At the end of phase 1, a midterm review was presented to KSC, JSC, and ER personnel for evaluation of the four possible options. At the conclusion of the midterm review, the option list was revised and direction for phase 2 was generated. This report is the culmination of the phase 2 investigation. Attached Appendix A presents the phase 1 investigation and midterm conclusions.

1.2 Organization of the Report

The information is presented in five major sections. Section 1, Introduction, describes the purpose of the report. Section 2, Phase 2 Investigation, describes all revised options with respect to certification requirements, maintainability, reliability, cost, advantages, and disadvantages. Section 3, Comparisons, describes points of interests for all options and compares the costs and benefits associated with choosing a particular option. Section 4, Summary and Conclusion, describes the investigation assessments from an independent standpoint and suggests at a minimum, required upgrades that would be necessary for transfer of the SLF meteorological system to the ER.

2. Phase 2 Investigation

Phase 2 was structured as a result of phase 1 determinations made at the midterm review. The decision to revise options 1 and 3 and investigate further with respect to certification, maintainability, reliability, and cost was actualized. The goal of phase 2 was to determine which revised option will be the most cost and benefit effective for transferring the SLF meteorological system to the ER. The following revised options were investigated and discussed at the final presentation on 30 September 1996.

2.1 Revised Options

The options were revised to investigate the costs and benefits associated with utilization of existing equipment, implementation of new equipment, and possible use of solar power at the SLF. The following revised options and labels will apply for the phase 2 study:

- **Option 1A**: Maintain the current SLF sensors and *Gespac* data processing system.

- **Option 1B**: Maintain the current SLF sensors and replace the *Gespac* data processing system with a new PC data processing system at the Landing Aids Control Building (LACB).

- **Option 1C**: Maintain the current SLF sensors and implement remote terminal units (RTUs) at the sites for data transmission to a new PC data processing system at the LACB.

- **Option 3A**: Install Launch Complex 39 (LC-39) *Climet* wind sensors and use *Climatronics* RTUs for data transmission to a new PC data processing system at the LACB using existing 12V DC power or solar powered arrays.

2.2 Option Assessments

All revised options are discussed below with respect to configuration, certification, maintainability, reliability, and costs. Solar power and a new real-time embedded data processing system will be discussed as separate options and referenced throughout the report. Cost estimates were based on a $70,000 man/year and software estimates were generated using the *Cocomo81* software estimation model.

2.2.1 Solar Power

The cost and benefits for the implementation of solar power will remain constant for all revised options.

2.2.1.1 Certification

Certification of solar power for any of the options will include the need for spares/parts, documentation, minimal training, testing, and revised drawing.

2.2.1.2 Maintainability

Solar power is used on many of the remote towers around the ER and maintenance has been minimal. Existing solar power is currently utilized where no other power source exists. Batteries for the solar power array will require replacement every few years, depending on the type and quality of battery installed.

2.2.1.3 Reliability

Solar power is very reliable with the duration of the battery charge during overcast periods representing the only concern. A typical 10W solar array with an 8 Ahr battery, will provide approximately five days of power during completely overcast days. After this time, replacement of the battery will be necessary. Higher Ahr rated batteries exist that would provide longer duration of power during overcast periods.

2.2.1.4 Costs

Table 1 displays rough order of magnitude (ROM) costs of purchasing, installing, testing, training, and drawing changes that will occur if solar power is implemented on a standalone basis.

Table 1: Solar Power ROM Costs

Solar Power Requirements	ROM costs
Purchase solar power array panels (3 with 1 spare)	$2,000
Install and test solar power arrays (3 man/weeks)	$4,500
Minimal training (1 man/week)	$1,500
Total	**$8,000**

- The price of $2,000 will be added for drawings changes in option 1A. This $2000 will not be included in other options because the cost of drawing changes for other changes will already be accounted for.

2.2.1.5 Advantages and Disadvantages

Advantages and disadvantages for solar power are summarized:

<u>ADVANTAGES</u>:
- Replaces existing method of supplying DC voltage over a copper phone line.
- Independent power to each site.
- Less expensive than installing AC power.

<u>DISADVANTAGES</u>:
- Added cost, training, and maintenance.
- Must monitor overcast periods for battery discharge.

2.2.2 Option 1A Assessment

- **Option 1A**: Maintain the current SLF sensors and *Gespac* data processing system.

Figure 1 displays the current meteorological configuration and associated equipment at the SLF.

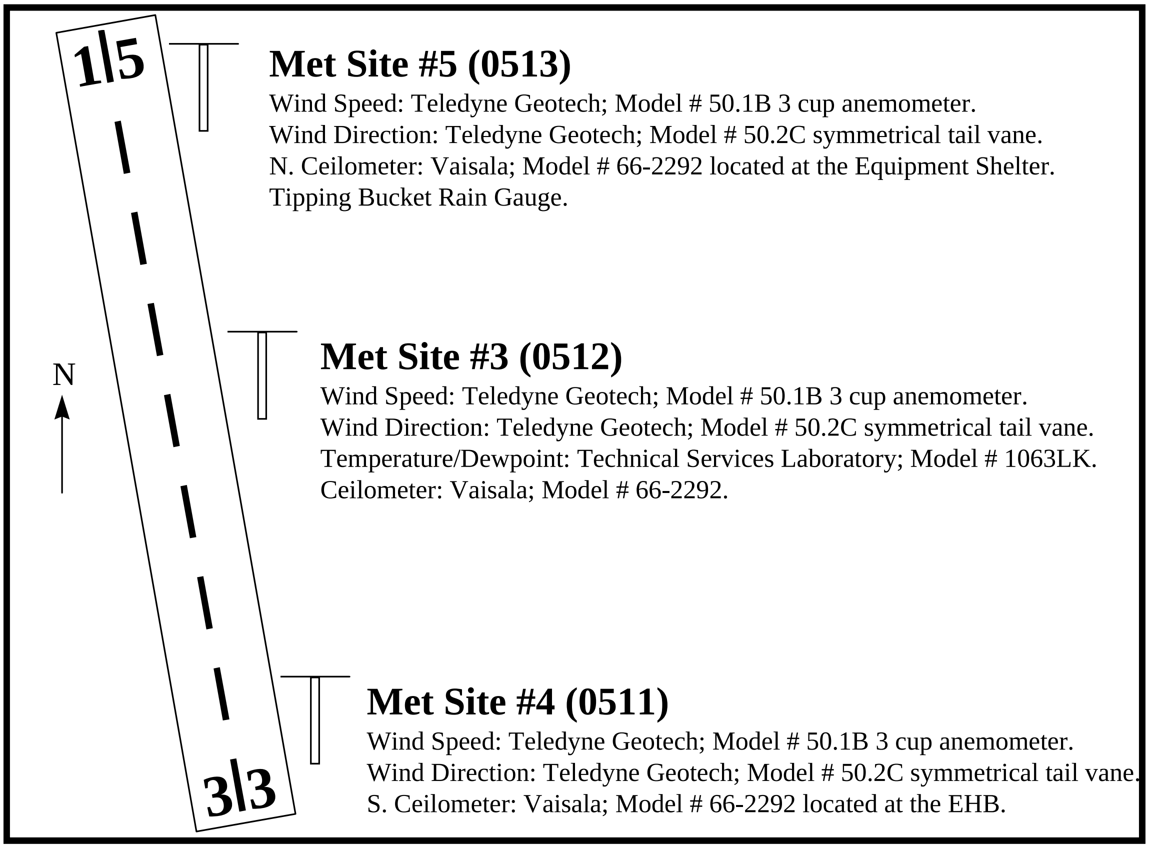

Figure 1: Current SLF Configuration

Table 2 displays the current SLF *Teledyne-Geotech* wind speed and wind direction specifications.

Table 2: Current SLF Wind Speed and Wind Direction Specifications

Specifications	Wind Speed *Teledyne-Geotech*	Wind Direction *Teledyne-Geotech*
Model	50.1B	50.2C
Range	0-90 knots	0-540°
Accuracy	+/- 0.5 knots	+/- 2°
Distance Constant	5 ft	3.7 ft
Threshold	0.6 knots	0.6 knots
Operating Temperature	-40° to 140° F	-40° to 140° F

Figure 2 displays the current SLF data processing flow from the sensors at the meteorological towers to the SLF Control Tower, Weather Station B, Launch Control Center (LCC), and into the Weather Information Network and Display System (WINDS) system at the Range Operations Control Center (ROCC). The raw data are currently transmitted from the sensors in analog format to the *Gespac* computer at the LACB where it is digitized and sent to the SLF Control Tower, Weather Station B, and the LCC at one sample per second. Transmission of the raw data from the LCC to the ROCC is converted to analog format, buffered into a RTU, and sent digitally at one minute averages to the ROCC WINDS system. Power for the sensors at meteorological sites 4 and 5 is currently supplied with 12 volts via phone line cable from the LACB. Power to meteorological site 3 is currently supplied with AC power from the LACB.

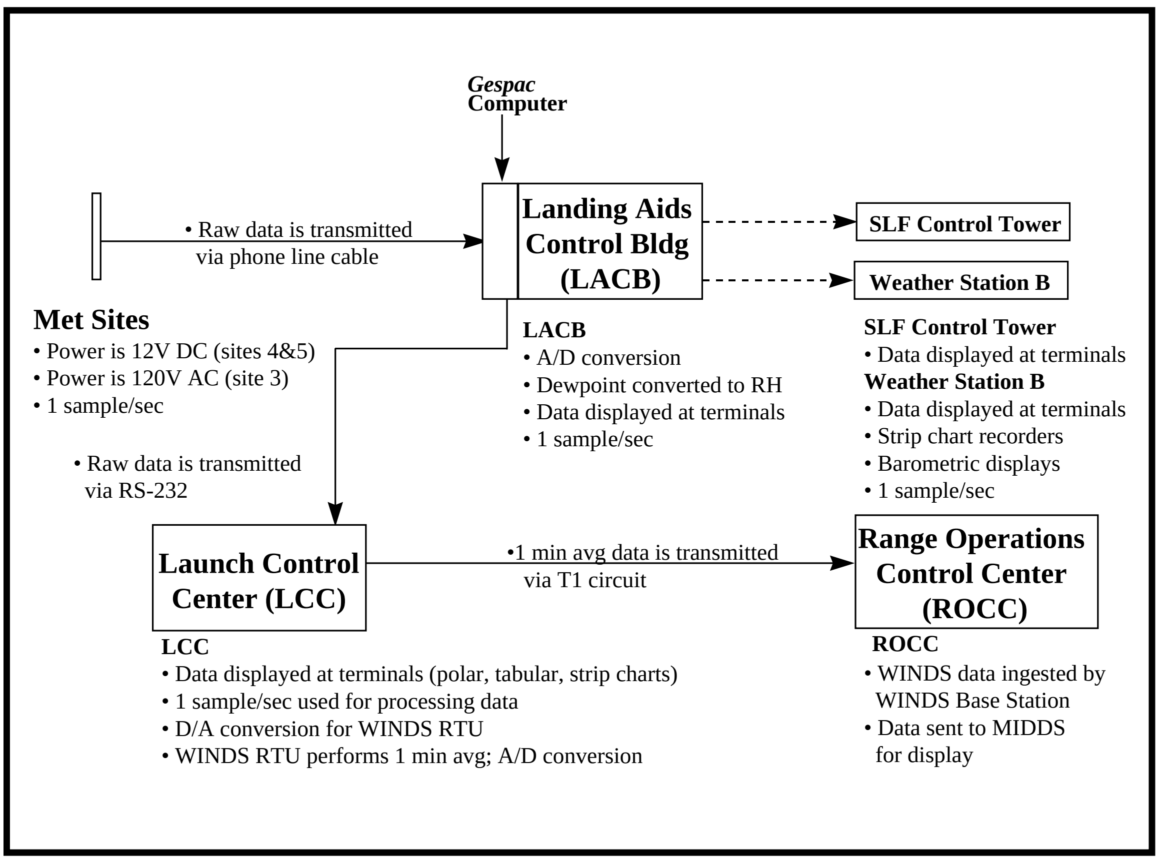

Figure 2: Current SLF Data Processing

2.2.2.1 Certification

Table 3 displays certification requirements that are satisfied or need to be satisfied for the current SLF meteorological configuration before acceptance by the ER System Operational Acceptance Board (SOAB).

Table 3: Certification Requirements for Option 1A

Certification Requirement Satisfied	YES	NO
Sparing	🗐	
Training	🗐	
O&M manuals, maintenance procedures, and drawings	🗐	
Software configuration		🗐
End-to-end testing		🗐

- Sparing is one-for-one with the wind sensors and ambient temperature/relative humidity (AT/RH) sensor. Maintenance (repair and replace) for the ceilometer units is completed at periodic intervals.

- CSR O&M is maintaining the current system and is trained on the equipment.

- O&M manuals, maintenance procedures, and drawings are available for all sensors and the *Gespac* data processing computer at the LACB.

- Software source code for the *Gespac* data processing computer is NOT available and will need to be located or rewritten. The code is available in a hard-copy format.

- End-to-end testing of the entire system will need to be conducted and documented before presenting the system to the ER SOAB.

2.2.2.2 Maintainability

The existing sensors have been maintained by CSR O&M. The wind sensors are reworked once a year for calibration and bearing maintenance and then rotated through the inventory.

The existing data flow configuration is maintained by CSR O&M. The soft-copy of the source code for the *Gespac* computer at the LACB has been unavailable. No updates or changes are possible unless the original soft-copy of the source code is located or new code is written. Because the current operating system (OS9) is no longer supportable with 68020 CPUs by the vendor, the original or equivalent compiler will also need to be located for software updates or new source code generation. There are spare CPUs for the *Gespac*, but once these are depleted a maintenance issue will develop with the unsupported operating system. If the CPUs are replaced with 68040 CPUs and associated operating system, a modern accessible compiler and associated equipment could be used for any new code development or changes that may occur. Software support will be required for any modifications at the SLF.

2.2.2.3 Reliability

DC voltage to sites 4 and 5 is currently supplied via copper phone line from the LACB to the towers with no recent reports of failures. AC power is supplied to site 3 with no UPS backup. The LACB has a generator for backup power.

The *Gespac* computer is an embedded real-time processing system located at the LACB. It contains two independent, redundant CPUs. Data from either CPU is accessible for display.

The *Teledyne-Geotech* wind sensors are of superior quality and no major failures have been experienced except for direct lightning strikes. Surge protection exists at the towers, but direct strikes have occurred and caused damage to the sensors and equipment at the LACB. A direct lightning strike to the tower followed a path from the site down the copper phone line and into the LACB destroying translator cards. There is isolation at the LACB that prohibits the lightning from continuing beyond the LACB.

Accuracy of the sensor processor (linearity) A/D outputs in the LACB is as follows:

- Wind Direction +/- 0.1%
- Wind Speed +/- 0.25%

2.2.2.4 Costs

Table 4 displays maximum ROM costs for the existing SLF configuration, option 1A. Costs will depend on the utilization of original source code or new code and acceptance by the ER of the testing completed in 1991 by NASA.

Table 4: Option 1A ROM Costs

Option 1A (Existing SLF Configuration)	**ROM costs**
Install upgraded CPUs and rewrite software for *Gespac* computer	$25,000*
Testing of complete end-to-end system	$20,000**
TOTAL	**$45,000*** **

* This cost would be reduced if the original software and compiler are located and utilized.
** This cost would be reduced if the original testing is accepted by the ER.
*** The implementation of solar power would be an additional $8,000.

2.2.2.5 Advantages and Disadvantages

The advantages and disadvantages for option 1A are summarized:

<u>ADVANTAGES</u>:

- Lowest cost option.
- Maintenance personnel are trained on the current system.
- Documentation is available.
- System testing was completed in 1991.
- The system has been functional since its inception without any major failures.

<u>DISADVANTAGES</u>:

- Current *Gespac* operating system with 68020 CPUs is not supported by vendor.
- Must locate original soft-copy of the source code and compiler or install new 68040 CPUs and rewrite code.
- System is susceptible to lightning strikes.

2.2.3 Option 1B Assessment

- **Option 1B**: Maintain the current SLF sensors and replace the *Gespac* data processing system with a new PC data processing system at the LACB.

Figure 3 displays the data processing flow with a new PC replacing the *Gespac* data processing system. (This would be the only change from option 1A.)

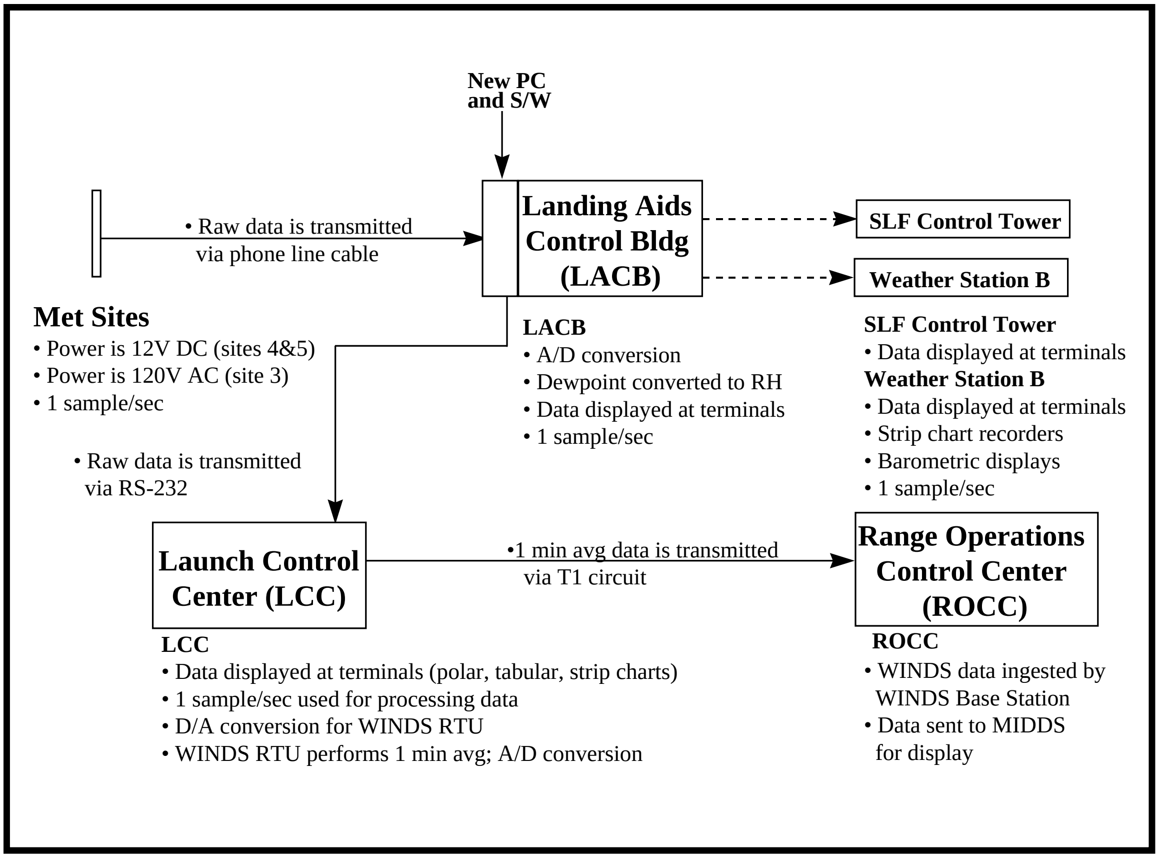

Figure 3: SLF Data Processing with New PC

2.2.3.1 Certification

Table 5 displays certification requirements that are satisfied or need to be satisfied for the SLF meteorological configuration with new PC data processing equipment before acceptance by the ER SOAB.

Table 5: Certification Requirements for Option 1B

Certification Requirement Satisfied	YES	NO
Sparing	🗐	
Training		🗐
O&M manuals, maintenance procedures, and drawings		🗐
Software configuration		🗐
End-to-end testing		🗐

- Sparing is one-for-one with the wind sensors and AT/RH sensor. Maintenance (repair and replace) for the ceilometer units is completed at periodic intervals.

- The new PC will require standard spare parts.

- CSR O&M is maintaining the current system and is trained on the current sensors but will require training on the new PC data processing system.

- O&M manuals, maintenance procedures, and drawings are available for all sensors. New manuals and system drawings will be required for the new PC.

- New software will have to be developed, implemented, and configured for the new PC data processing equipment at the LACB.

- End-to-end testing of the entire system will need to be conducted and documented before presenting the system to the ER SOAB.

2.2.3.2 Maintainability

The existing sensors have been maintained by CSR O&M. The wind sensors are reworked once a year for calibration and bearing maintenance and then rotated through the inventory.

The new PC data processing system will require software support for any modifications at the SLF.

2.2.3.3 Reliability

DC voltage to sites 4 and 5 is supplied via copper phone line from the LACB to the towers with no recent reports of failures. AC power is supplied to site 3 with no UPS backup. The LACB has a generator for backup power.

The *Teledyne-Geotech* wind sensors are of superior quality and no major failures have been experienced except for direct lightning strikes. Surge protection exists at the towers, but direct strikes have occurred and caused damage to the sensors and equipment at the LACB. A direct lightning strike to the tower followed a path from the site down the copper phone line and into the LACB destroying translator cards. There is isolation at the LACB that prohibits the lightning from continuing beyond the LACB.

A PC data processing system poses the risk of the hard disk faults and will require a backup PC processing system for redundancy. Because the SLF meteorological system is a critical system, built-in safeguards should be implemented such as UPS, surge protection, dual independent processing capabilities, and security.

2.2.3.4 Costs

Table 6 displays ROM costs for option 1B.

Table 6: Option 1B ROM Costs

Option 1B (Existing SLF configuration with new PCs)	ROM costs
Purchase and install new PC with backup and A/D outputs	$10,000
Develop new software for PC data processing system	$25,000
Drawings and documentation revised	$10,000
Training	$2,000
Testing of complete end-to-end system	$20,000
TOTAL	**$67,000***

* The implementation of solar power will be an additional $8,000.

2.2.3.5 Advantages and Disadvantages

The advantages and disadvantages for option 1B are summarized:

ADVANTAGES:

- The *Gespac* system would be replaced with supported processing capabilities.
- A new PC system would have some hardware COTS compatibility.

DISADVANTAGES:

- Added cost, training, and maintenance.
- The current *Gespac* is a real-time embedded system and replacement with a PC data processing system is not common practice.
- Modifications to the operating system will be extensive and standard PC capabilities will be lost.
- Additional security measures would need to be provided to ensure configuration control of the PC operating system.

2.2.4 Option 1C Assessment

- **Option 1C**: Maintain the current SLF sensors and implement RTUs at the sites for data transmission to a new PC data processing system at the LACB.

This option will discuss the implementation of RTUs with and without front-end translators which eliminate the need for software modification in the RTU for periodic calibration. Also, the comparison between a new PC data processing system and the existing *Gespac* system will be discussed.

Figure 4 displays the current SLF sensors with proposed RTUs and new PCs for the data processing at the LACB. This configuration will be powered with the existing 12V DC or installation of a solar power system for sites 4 and 5. The data will be digitized at the site and sent at one sample per second to an updated PC data processing system at the LACB. Beyond this point, data processing will remain unchanged from the current SLF configuration.

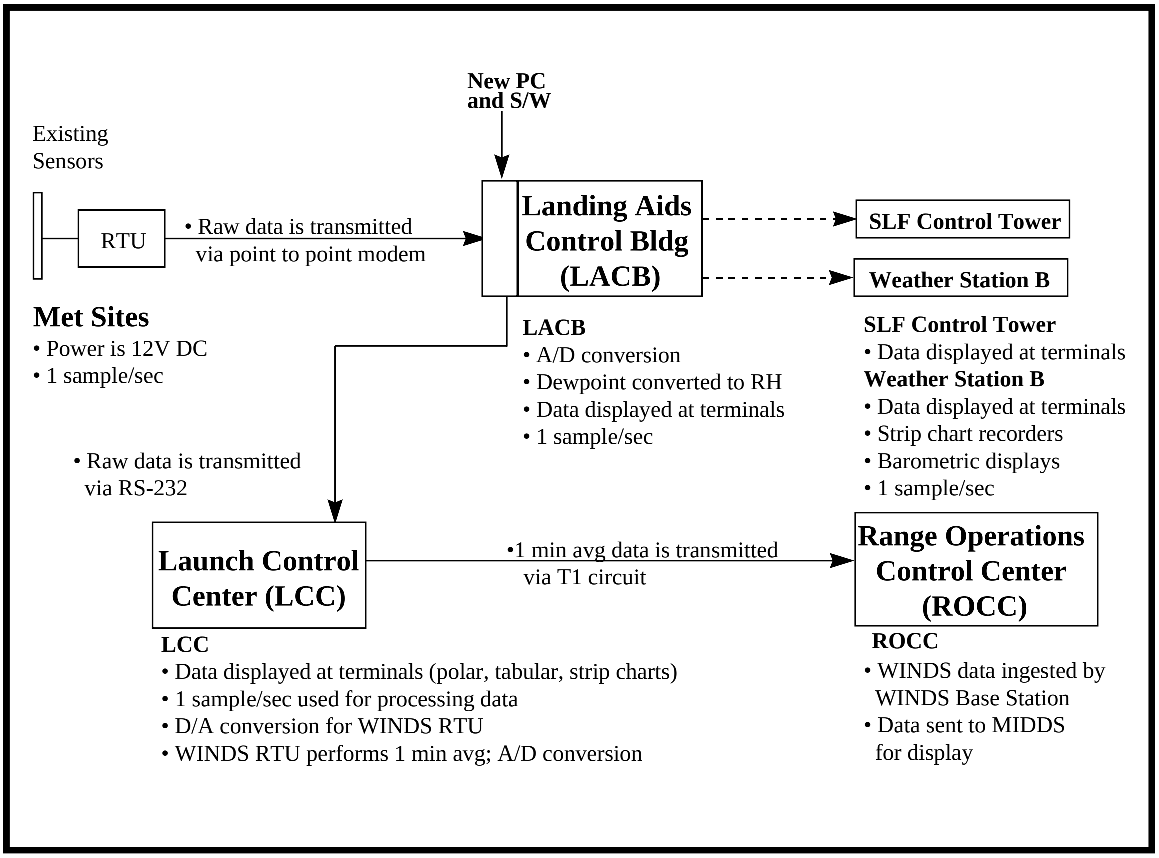

Figure 4: SLF Configuration with Proposed RTUs and New PCs

2.2.4.1 Certification

Table 7 displays certification requirements that are satisfied or need to be satisfied for the SLF meteorological configuration with RTUs and new PC data processing system before acceptance by the ER SOAB.

Table 7: Certification Requirements for Option 1C

Certification Requirement Satisfied	YES	NO
Sparing	🗐	
Training		🗐
O&M manuals, maintenance procedures, and drawings		🗐
Software configuration		🗐
End-to-end testing		🗐

- Sparing is one-for-one with the wind sensors and AT/RH sensor. Maintenance (repair and replace) for the ceilometer units is completed at periodic intervals.

- Additional spare parts will be required for any applicable new hardware item. (RTUs, PCs, front-end translators, etc.)

- CSR O&M is maintaining the current system and is trained on the equipment. Implementation of new hardware equipment will require training.

- O&M manuals, maintenance procedures, and drawings are available for current sensors. Manuals for the new hardware equipment will be required. Drawing changes will be required for installation of any new hardware equipment.

- New software will have to be developed and configured if the new PC data processing system at the LACB is implemented. If the existing *Gespac* system is used, the soft-copy of the source code for the *Gespac* data processing computer is NOT available and will need to be located or rewritten. The code is available in a hard-copy format.

- End-to-end testing of the entire system will need to be conducted and documented before presenting the system to the ER SOAB.

2.2.4.2 Maintainability

Currently, the wind sensors are reworked once a year for calibration and bearing maintenance and then rotated through the inventory.

For sensor accuracy, RTUs at the site require periodic calibration which is accomplished in the RTU software. This will create a need for re-certification when the configured software is modified. Front-end translators could be installed which would prevent the need for software adjustments in the RTU. All adjustments could be completed inside the front-end translator hardware.

The new PC data processing system will require software support for any modifications.

The current *Gespac* data processing system could be interfaced with option 1C using RTUs. Modifications would entail swapping out the A/D cards at the *Gespac* system and installing RS-232 data cards. As in option 1A, the existing data flow configuration has been maintained by CSR O&M. The soft-copy of the source code for the *Gespac* computer at the LACB has been unavailable. No updates or changes are possible unless the original soft-copy of the source code is located or new code is written. Because the current operating system (OS9) is no longer supportable with 68020 CPUs by the vendor, the original or equivalent compiler will also need to be located for software updates or new source code generation. There are spare CPUs for the *Gespac*, but once these are depleted a maintenance issue will develop with the unsupported operating system. If the CPUs are replaced with 68040 CPUs and associated operating system, a modern accessible compiler and associated equipment could be used for any new code development or changes that may occur. Software support will be required for any modifications at the SLF.

2.2.4.3 Reliability

The sensors are of superior quality and have not had any major failures except for lightning strikes.

RTUs are optically isolated, presenting an open path for potential lightning strikes. This would isolate any damage to the tower and prevent the lightning from traveling to the LACB. RTUs digitize data at the site and have a low noise susceptibility providing reliable data on the communication lines.

The accuracy of RTU digital outputs will vary with manufacturer. An example of RTU accuracy at LC-39:

- *Climatronics* RTU output accuracy: +/- 0.1% (@ 0°-40°C)

A PC data processing system poses risks of hard disk faults and will require a backup PC processing system for redundancy. Because the SLF meteorological system is a critical system, built-in safeguards should be implemented such as UPS, surge protection, dual independent processing capabilities, and security.

The *Gespac* computer is an embedded real-time processing system located at the LACB and processing is achieved with two independent, redundant CPUs. Data from either CPU is accessible for display.

2.2.4.4 Costs

Table 8 displays ROM costs for option 1C, the existing SLF configuration with RTUs and PC data processing system installed.

Table 8: Option 1C ROM Costs

Option 1C (Existing SLF with RTUs and new PC installed)	ROM costs
Purchase, install, and test new RTUs	$21,000
Purchase and install new PC with backup with A/D outputs	$10,000
Develop new software for PC data processing system	$25,000
Drawings and documentation	$10,000
Training	$5,000
Testing of complete end-to-end system	$20,000
TOTAL	**$91,000***

* The implementation of solar power will be an additional $8,000. The use of the existing *Gespac* computer and code will reduce costs by $35,000. If new CPUs and code are installed, costs will be reduced by $10,000. (Training will also be reduced by a minimal amount.)

Table 9 displays additional ROM costs of adding front-end processors to the sites for use with the RTUs. This would eliminate the need for software modification in the RTU for periodic calibration. All costs include spares for each site.

Table 9: Front-End Processor Costs

Front-End Processors for *Teledyne-Geotech* Sensors	ROM costs
Stainless steel enclosures	$4,680
Geotech wind translator assemblies	$2,100
Signal line surge protection	$900
Non-recurring engineering	$900
Cabling	$510
TOTAL	**$9,090**

2.2.4.5 Advantages and Disadvantages

Advantages and disadvantages for option 1C are summarized:

ADVANTAGES:
- Optical isolation at the sites for lightning.
- Minimal overall accuracy gain.
- The *Gespac* system would be replaced with a supported operating system and processing capabilities if a new PC is utilized.
- A new PC system would have some hardware COTS compatibility.

DISADVANTAGES:
- Added cost, training, and maintenance.
- May require re-certification if RTUs need periodic calibration unless front-end translators are provided which add cost and maintenance.

- The current *Gespac* is a real-time embedded system and replacement with a PC data processing system is not common practice.
- Modifications to the operating system will be extensive and standard PC capabilities will be lost.
- Additional security measures would need to be provided to ensure configuration control of the PC operating system.

2.2.5 Option 3A Assessment

- **Option 3A**: Implement LC-39 *Climet* wind sensors and *Climatronics* RTUs for data transmission to a new PC data processing system at the LACB utilizing existing 12V DC power or solar powered arrays.

The certification, maintainability, reliability, costs, advantages, and disadvantages associated with installing front-end translators and utilizing the existing *Gespac* computer apply to option 3A.

Table 10: *Climet* Wind Speed and Wind Direction Specifications

Specifications	Wind Speed *Climet*	Wind Direction *Climet*
Model	011-4	012-16
Range	0-95 knots	0-539°
Accuracy	+/- 0.13 knots	+/- 3 °
Distance Constant	5 ft	3.2 ft
Threshold	0.5 knots	0.6 knots
Operating Temperature	-50° to 155° F	-50° to 155° F

Figure 5 displays proposed option 3A with *Climet* sensors and *Climatronics* RTUs and a new PC data processing system at the LACB. This configuration will be powered with the existing 12V DC at sites 4 and 5 and 120VAC at site 3, or installation of solar power for all sites. The data will be digitized at the site and sent at one sample per second to an updated PC computer data processing system at the LACB. Beyond this point, data processing will remain unchanged from the current SLF configuration.

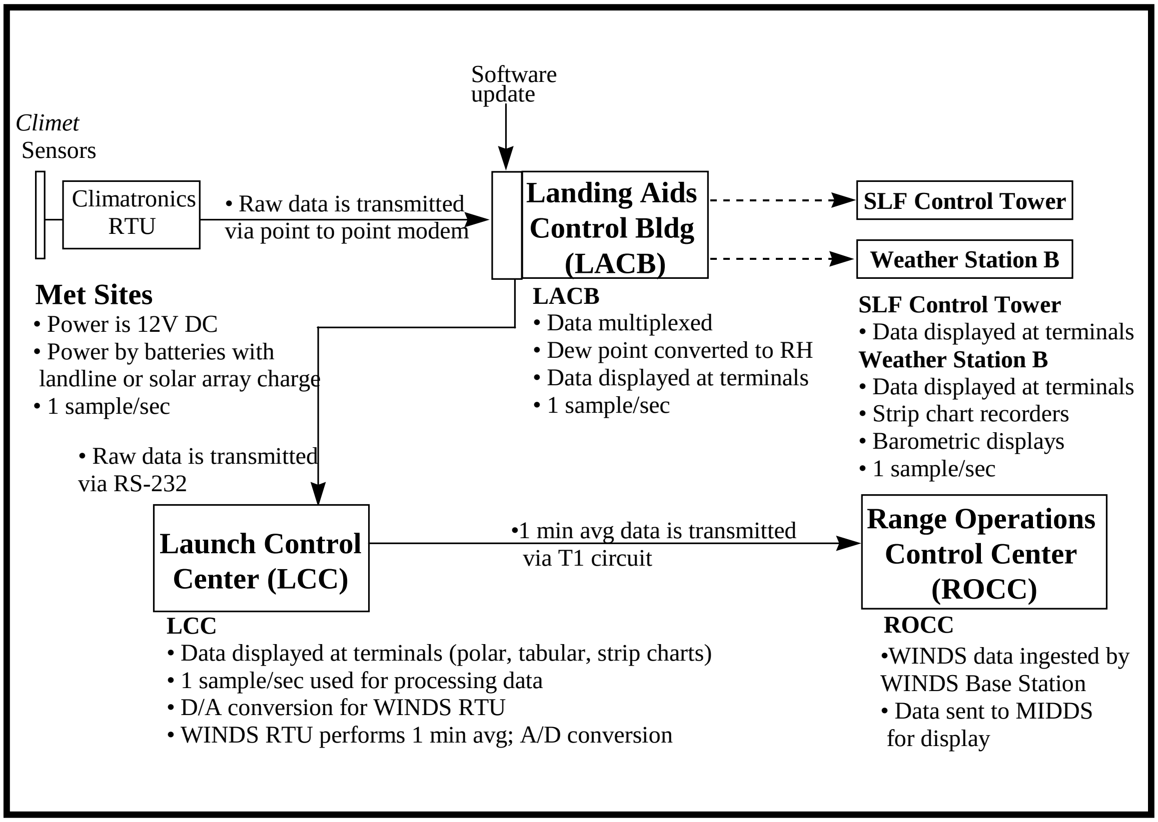

Figure 5: SLF with LC-39 Equipment

2.2.5.1 Certification

Table 11 displays certification requirements that are satisfied or need to be satisfied for using *Climet* sensors, *Climatronics* RTUs, and a new PC data processing system before acceptance by the ER SOAB.

Table 11: Certification Requirements for Option 3A

Certification Requirement Satisfied	YES	NO
Sparing		🗐
Training		🗐
O&M manuals, maintenance procedures, and drawings		🗐
Software configuration		🗐
End-to-end testing		🗐

- LC-39 sensors and spares are available in the NASA inventory.

- United Space Alliance (USA) is maintaining the current LC-39 system and training will be necessary for SLF O&M personnel on the new sensors, RTUs, and new PC data processing system at the LACB.

- O&M manuals, maintenance procedures, and drawings are available for the LC-39 *Climet* sensors. New system drawings will be required with the addition of new sensors, RTUs, and new PC data processing system at the LACB.

- New software will have to be developed, implemented, and configured for the new PC data processing system at the LACB.

- End-to-end testing of the entire system will need to be conducted and documented before presenting the system to the ER SOAB.

2.2.5.2 Maintainability

Calibration for the LC-39 sensors is completed at six month and one year intervals for the temperature and wind sensors respectively.

For sensor accuracy, RTUs at the site require periodic calibration which is accomplished in the RTU software. This will create a need for re-certification when the configured software is modified. Front-end translators could be installed which would prevent the need for software adjustments in the RTU. All adjustments could be completed inside the front-end translator hardware.

The new PC data processing system will require software support for any modifications.

2.2.5.3 Reliability

USA maintenance personnel report that no *Climatronics* RTU has been replaced since their inception in 1992. *Climet* sensors are routinely replaced for maintenance reasons only. Accuracy of the overall system is reported as being extremely accurate.

- Accuracy of *Climatronics* RTU output: +/- 0.1% (@ 0°-40°C)

RTUs are optically isolated, presenting an open path for potential lightning strikes. This would isolate any damage to the tower and prevent the lightning from traveling to the LACB. RTUs digitize data at the site and have a low noise susceptibility providing reliable data on the communication lines.

A PC data processing system poses risks of hard disk faults and will require a backup PC processing system for redundancy. Because the SLF meteorological system is a critical system, built-in safeguards should be implemented such as UPS, surge protection, dual independent processing capabilities, and security.

2.2.5.4 Costs

Table 12 displays ROM costs for configuring the SLF with LC-39 sensors, RTUs and associated data processing equipment, option 3A.

Table 12: Option 3A ROM Costs

Option 3A (LC-39 Sensors with RTUs and PC installed)	ROM costs
LC-39 *Climet* sensors installed at each local SLF met site	$15,000
Climatronics RTU and associated software installed	$21,000
Purchase and install new PC with backup with A/D outputs	$10,000
Develop new software for PC data processing system	$25,000
Drawing and documentation changes	$10,000
Testing of complete end-to-end system	$20,000
Training	$5,000
TOTAL	**$106,000**

2.2.5.5 Advantages and Disadvantages

Advantages and disadvantages for option 3A are summarized:

ADVANTAGES:

- Optical isolation at the sites for lightning.
- Minimal overall accuracy gain.
- The *Gespac* system would be replaced with a supported operating system and processing capabilities if a new PC is utilized.
- A new PC data processing system would have some hardware COTS compatibility.

DISADVANTAGES:

- No performance gain from replacing existing sensors.
- Added cost, training, and maintenance.
- May require re-certification if RTUs need periodic calibration unless front-end translators are provided which add cost and maintenance.
- The current *Gespac* is a real-time embedded system and replacement with a PC data processing system is not common practice.
- Modifications to the operating system will be extensive and standard PC capabilities will be lost.
- Additional security measures would need to be provided to ensure configuration control of the PC operating system.

2.2.6 Real-Time Embedded System

An option to the current *Gespac* data processing system, or replacement of the *Gespac* with PCs, is replacement with a new real-time embedded system. This system would replace the current *Gespac* computer and provide the meteorological system with modern processing capabilities. The real-time embedded system offers a better solution than a PC replacement solution in terms of compatibility, customization, security, and cost.

For example, a *Gespac* GDS 6000 Series real-time data acquisition system could be used as a replacement of the current *Gespac* system and would provide the ability to drive many local or remote input/output (I/O) lines in a real-time embedded system. The GDS 6000 Series systems are based on a 25 MHz MC68030 CPU and programmable under the *INVIEW* real-time control package for customizing control and display functions. *INVIEW* is also designed to interface to a built-in graphical user interface and could provide the system with future graphical display upgrades. *INVIEW* works with the OS9 operating system and is the integrated man-machine interface. With an attached monitor, a pop-up screen keypad allows system interface control for customization of outputs to the end-user or any updates that may be required. For security, *INVIEW* supports alarm and event logging mechanisms which can trigger alarms in any desired circumstance. For about the price of one PC as presented in Table 13, a real-time embedded system made for applications such as the SLF can be purchased with less modifications and more upgrade potential than the PC option.

Table 13: Optional Real-Time Embedded System

Optional *Gespac* 6000 Series Real-Time Embedded System	**ROM costs**
Backplane (12 slots)	$350
Multiprocessor card (2)	$800
Multifunction card (2)	$800
Serial I/O card (2)	$600
Memory card (1)	$300
TOTAL	**$2850***

* Software required for the SLF application may be custom tailored by the *Gespac* vendor and is not reflected in this price. The price is not available at this time and would vary according to the decision of using a RTU and sending digital data, or not using a RTU and sending analog data. A $25,000 software development effort that was applied to other options can be used as a "worst case scenario" comparison, although preliminary indications reveal a much less expensive effort. This is for hardware cost comparison only. Added cost will be required for a rack mount system and any custom peripherals.

3. Comparisons

Comparisons and important issues are displayed below for all revised options.

3.1 Certification

Table 14 displays requirements that are satisfied or need to be satisfied for all revised options (without added modifications) before acceptance by the ER SOAB.

Table 14: Certification Satisfaction Table for all Options

Option	1A		1B		1C		3A	
Satisfied	Yes	No	Yes	No	Yes	No	Yes	No
Sparing	🗐		🗐		🗐			🗐
Training	🗐			🗐		🗐		🗐
O&M manuals, MPs, and drawings	🗐			🗐		🗐		🗐
Software configuration		🗐		🗐		🗐		🗐
End-to-end testing		🗐		🗐		🗐		🗐

3.2 Maintainability Points of Interest

1. Both *Teledyne-Geotech* and *Climet* wind sensors will require calibration annually.

2. No updates or changes to the *Gespac* computer are possible until the soft-copy of the source code and compiler have been located or new code is written. The current operating system is not supported by the vendor.

3. All options will require software support on the data processing system.

4. Batteries for solar power arrays will require replacement every few years, depending on the type and quality of battery installed at the sites.

5. The LC-39 *Climatronics* RTU software is reworked on a six month basis due to performance requirements. This would require re-certification each time a change occurs in the software unless front-end translators are installed.

3.3 Reliability Points of Interest

1. Solar power reliability concerns stem from the battery charge duration during overcast periods. With the current sensors at the SLF, a typical 10W solar array with an 8 Ahr battery, would provide approximately five days of power during completely overcast days.

2. Lightning has followed a path from the site down the copper phone line and into the LACB with the existing SLF configuration.

3. Accuracy of current sensor translators A/D output at the LACB:
   Wind Direction +/- 0.1%
   Wind Speed +/- 0.25%

4. Accuracy of LC-39 RTU output:
   Climatronics RTU +/- 0.1% (@ 0°-40°C)

5. A PC data processing system poses risks of hard disk faults and will require a backup PC data processing system for redundancy. Because the SLF meteorological system is a critical system, built-in safeguards should be implemented such as UPS, surge protection, dual independent processing capabilities, and security. The real-time embedded system offers a more sensible replacement option.

3.4 Costs

Table 15 displays ROM costs for all options under investigation.

Table 15: ROM Costs for all Options

Options	ROM costs
1A- Existing SLF system	$45,000
1B- Existing SLF system with PCs and S/W	$67,000
1C- Existing SLF system with RTUs, PCs, and S/W	$91,000
3A- LC-39 equipment with existing power	$106,000
Options 1C and 3A Modifications	
Front-end translators	Add $9,090
Use existing *Gespac* with existing code	Subtract $35,000
Use existing *Gespac* with new CPUs and new code	Subtract $10,000

4. Summary and Conclusion

4.1 Summary

The phase 2 investigation concluded with a presentation from ENSCO to representatives from KSC, JSC, and the ER. Many alternatives are possible for satisfying the certification requirements needed for the successful transfer of the SLF meteorological system to the ER. The revised options investigated above represented four of the many solutions that would benefit the overall system.

The study focused on cost and benefits for all options and discussed each in terms of certification, maintainability, reliability, advantages, and disadvantages.

The investigation determined that the minimum criterion required for certification and sustainability is to locate the original soft-copy of the source code and compiler. This would be the most cost beneficial of all options. All communities agree that this is the most critical issue with the existing system. Without the existing soft-copy of the source code, no changes, updates, or configuration of the software is possible. ENSCO believes it has located the soft-copy and compiler, and efforts will be made with the proper personnel to obtain the required items. If the original soft-copy of the source code can not be obtained, an alternative option would be to generate new source code from the existing hard-copy, as long as the existing or equivalent compiler is located. The reason for obtaining the original or equivalent compiler, is the current *Gespac* operating system with 68020 CPUs is no longer supported by the vendor and new compilers on the market will not duplicate the source code. Another option would be to upgrade to newer CPUs (68040) and associated operating system, rewrite the code, and use a modern compiler that would be supportable for future needs.

Other options investigated the concept of replacing the *Gespac* data processing system with a PC system. Replacement of a real-time embedded system with a PC system is normally not common practice. Although possible, many real-time embedded data processing systems exist that are more cost effective and better suited for replacement than a PC system. Also, more capabilities for future upgrades are inherently designed in many of the possible replacements, such as graphical display capability and custom outputs for the end user.

RTUs offer an advantage in terms of better lightning isolation from the tower. Although lightning isolation presently exists in the form of surge protection at the sites, direct lightning strikes can potentially reach the LACB and destroy associated hardware. This scenario has occurred recently and destroyed translator cards. Accuracy gain with the RTUs will be insignificant when used with the existing *Teledyne-Geotech* sensors, also added maintenance and cost for the front-end translators will be required if potential certification issues exist with required periodic calibration of the RTU software. Replacement of the *Gespac* data processing system would not be necessary with this option, only replacement of the A/D cards with RS-232 cards will be required. The software would remain unchanged, but the same issues apply with configuring the software that were mentioned above.

Solar array systems offer independent power at the sites and would replace the current 12V DC power supplied with copper phone lines from the LACB. Power to the sites has been reliable following the upgrades to the communication lines. The implementation of solar power will add cost and maintenance to an existing functional system.

No gain is obvious by replacing the existing wind sensors with LC-39 type sensors. The current *Teledyne-Geotech* wind sensors are high quality sensors and specifications meet or exceed other replacements investigated.

4.2 Conclusion

At the conclusion of the presentation, the attendees agreed that the minimum criteria needed for transfer and certification to the ER would be to locate the original soft-copy of the source code and compiler. Because of the limited amount of spares and the non-supportable operating system, the second best possible solution as described in option 1, is to upgrade the *Gespac* to a supportable operating system by replacing the 68020 CPUs with 68040 CPUs and rewriting the software. This would be the most beneficial of all options investigated in terms of cost and sustainment. All other options have particular benefits associated with their implementation, but all offer different methods of supplying the same data to the end user and are not mandatory at this time for certification.

5. References

This study was completed by investigating a matrix of official documentation, specifications from applicable product lines, and interviews with various KSC, ER, and vendor personnel.

5.1 Documentation

System Documentation List, SLF Meteorological System: Doc. No. 81K01184, November 1993

Software Design Package, SLF Meteorological System: Doc. No. 81K00772, Rev A, July 1993

Operational Performance Specifications, SLF Meteorological System: Doc. No. 81K00715, June 1990

SLF Meteorological System: Doc. No. 81K00768, September 1992

System Acceptance Test Plan and Report, SLF Meteorological System: Doc. No. 81K00775, July 1992

Acceptance Test Procedures for the SLF: Doc No. KSCE-827-0240, November 1993

SLF MET Wind Direction, Wind Speed Sensor O&M Manual: Doc No. VEN-2001, Rev B, March 1992

SLF MET Temperature and Dewpoint Current Transmitter O&M Manual: Doc No. VEN-2002, November 1992

Eastern Range Instrumentation Handbook, June 1995

Final Report on the Evaluation of ASOS for KSC SLF: ENSCO, 1994

National Instruments Instrumentation Reference and Catalogue, 1996

Climet Instrumentation Wind Sensor Specifications

Climatronics Remote Terminal Unit Specifications

Sutron Remote Terminal Unit Specifications

R.M. Young Wind Sensor Specifications

ASOS Instruments Specifications

5.2 Interviews

The following list is a combination of participants in the study and personnel interviewed for data gathering.

Name	**Organization**
Adams, Si	CSR 4140
Adang, Tom, Col.	45WS/CC
Barton, Dan	USA 52-53
Bellue, Dan	NASA/SMG
Bogdon, Mona	45SPW/LG
Boyd, Bill	45WS/SYA
Conant, Pete	SMC/CWP
Gardner, Tim	NASA/SMG
Goldfarb, Scott	Climatronics Rep.
Harms, Dewey, Maj.	45WS/SY
Harris, Wayne	NYMA
Herring, Hal	CSR 4140
Jones, Dennis	CSR 4140
Kiel, Larry	USA
Knox, Tom	SMC/CWP
Lafosse, Richard	NASA/SMG
Madura, John	NASA/PH-B3
Merceret, Frank	NASA/PH-B3
Mulligan, Pat	NYMA
Nguyen, Joe	45MXR/MXRS
Nurge, Mark	KSC/PZ-B2
Oram, Tim	NASA/SMG
Tuttle, Steve	CSR 4140
Vincent , Guy	CSR 4140
Wiedkind, Dave	INET