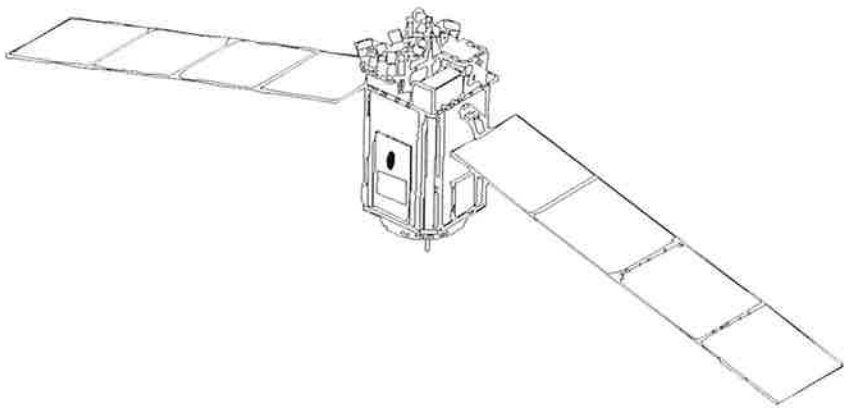
SDL/95-006
Revision B

SABER
INSTRUMENT REQUIREMENTS DOCUMENT



Submitted to:

National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-0001

Attn: Bill Roettker

Contract No. NAS1-20467
DRL Item No. 1

6 April 1998

SABER INSTRUMENT REQUIREMENTS DOCUMENT

RECORD OF REVISIONS

Revision	Date of Revision	Description of Changes
A	11/5/96	1. The Foreword was changed to reflect the current contract number and eliminate reference to items that have been deleted from the document. 2. The Table of Contents was updated to reflect changes to the document. 3. The O_3 filter 5% relative transmission limits (cm^{-1}) were changed from 1010-1120 to 1010-1140 in Tables 2 and 4. 4. Section 3.4 (instrument modes) and all of its subsections were deleted. 5. Paragraphs 4.1.1, 4.1.3, and 4.1.4 were deleted and the two remaining paragraphs were renumbered. 6. Sections 4.3, 4.4, and 4.5 and all of their subsections were deleted. 7. The appendix, SABER Goals and Requirements Tree, was deleted.
B	4/6/98	1. Updated Table 4 to reflect contractual changes to focal plane array channel spectral response. 2. Updated paragraphs 2.2 through 2.8 and Table 2 to reflect changes made to Table 4. 3. Updated Figure 3 to reflect current focal plane array channel locations.

Lorin J. Zollinger
SDL/USU SABER Program Manager

Richard K. Austin
SDL/USU Quality Assurance/Reliability Manager

FOREWORD

NASA Langley Research Center (LaRC) awarded contract NAS1-20467 to the Space Dynamics Laboratory at Utah State University (SDL/USU) to develop instrumentation for the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) investigation.

This Instrument Requirements Document (IRD), submitted in compliance with the contract statement of work, presents the science objectives and the performance, functional, and design requirements for the SABER instrument. The information presented within this document is based on information provided by NASA LaRC in a suggested IRD document.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPLICABLE DOCUMENTS

Joint LaRC-SDL/USU SABER Proposal submitted July 1992

1. INTRODUCTION

1.1 Background

SABER, as defined in a joint LaRC-SDL/USU proposal submitted in July 1992 in response to AO 92-OSSA-1, is the baseline instrument definition. The design requirements of that proposal with subsequent changes are included herein but are not intended to inhibit or restrict the tradeoff studies and the instrument specification document being developed for this task.

1.2 Mission Description

The overall goal of the Sounding of the Atmosphere Using Broadband Emission Radiometry (SABER) experiment is to achieve a major improvement in our understanding of the fundamental processes governing the energetics, chemistry, dynamics, and transport processes of the mesosphere and lower thermosphere. Even though this region of our atmosphere is vital to atmospheric heating and cooling and in coupling of processes in the high atmosphere to the stratosphere, it is essentially unexplored on a global scale. SABER will provide global measurements of the key parameters needed to study (1) the thermal structure of the region; (2) the O_y, HO_y, NO_y chemistry; (3) the energetics and distribution of radiatively active species; (4) dynamics and transport processes; and (5) important polar processes. The SABER instrument will measure the science parameters to the projected 1 σ retrieval accuracies indicated in Table 1.

Table 1. Projected 1 σ Retrieval Accuracies

Parameter		Measurement Range /Altitude (km)	1 σ Accuracy within Range
Temperature	T	10-100	< 3 K (16-90 km)
O_y	O_3	15-100	< 25% (50-90 km)
HO_y	H_2O	15-80	< 20% (30-70 km)
NO_y	NO	90-180	< 50% (100-150 km)
Carbon Species	CO_2	85-150	< 30% (95-140 km)
Energetics	$O_2(^1\Delta)$ $OH(\upsilon=7,8,9)$ $OH(\upsilon=3,4,5)$ $NO(\upsilon)$ $O_3(\upsilon_3)$ $CO_2(\upsilon_2)$	50-105 80-100 80-100 90-180 15-100 10-120	

The SABER operational system may be considered to include the five objects in the functional flow block diagram of Figure 1. These five objects interact and comprise the total SABER system operational model. Typical system interactions are shown for reference in the SABER behavior diagram of Figure 2. The system operational interactions must be considered in the detailed design of the SABER instrument.

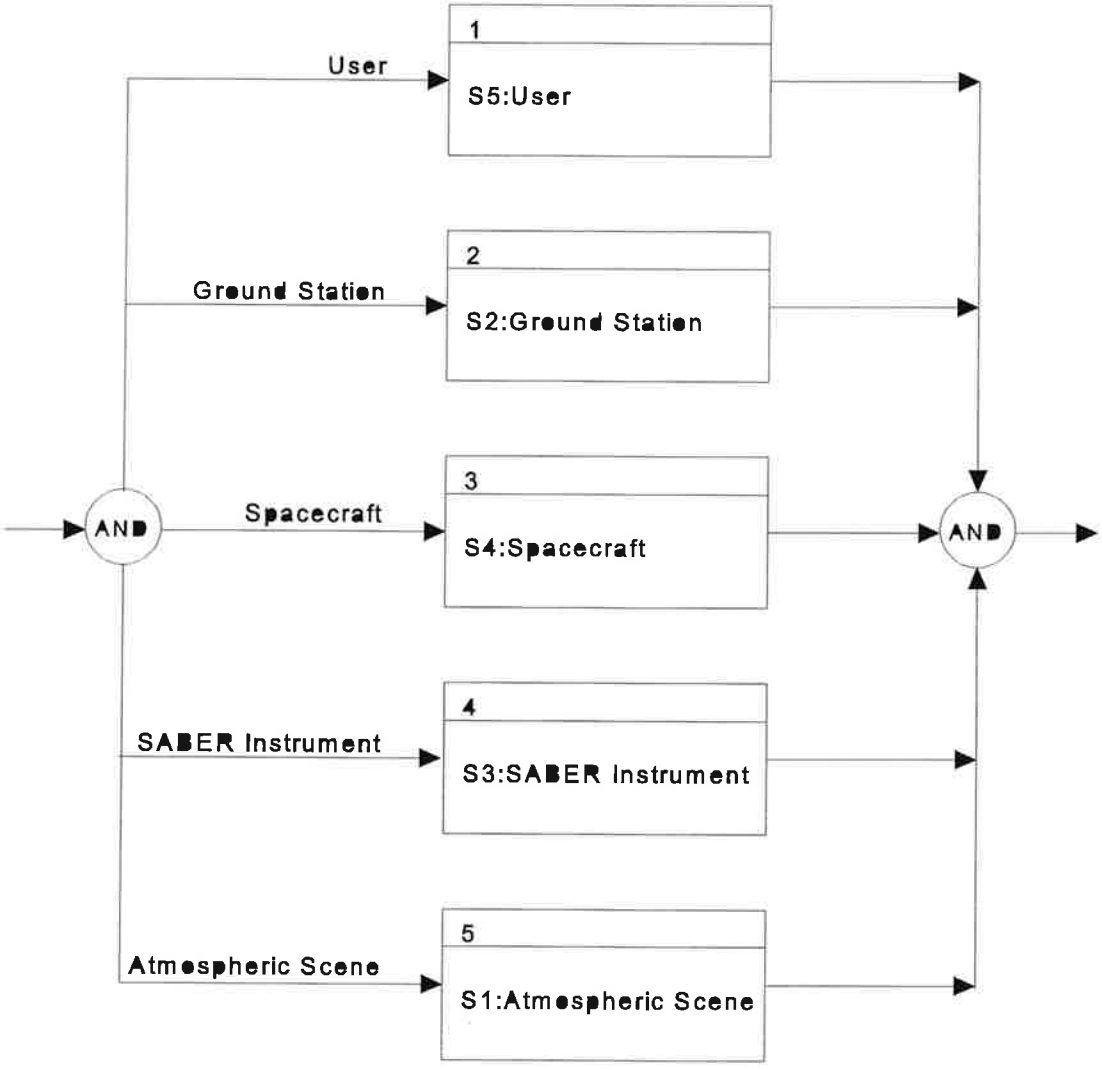


Figure 1. SABER Functional Flow Block Diagram

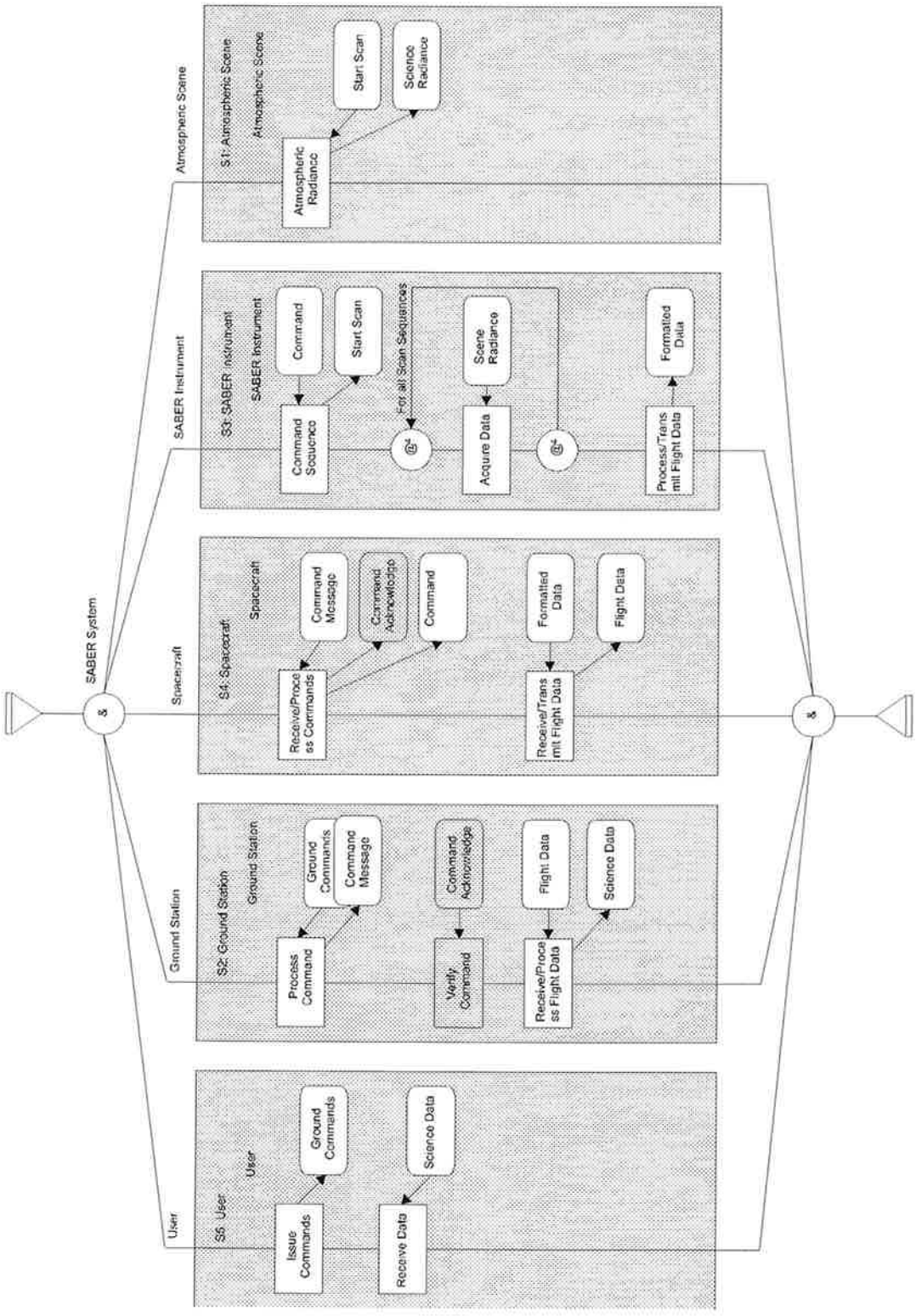


Figure 2. SABER Behavior Diagram

The SABER experiment will operate from an unmanned satellite in a circular orbit of 600 km altitude and 74.4° inclination. The instrument shall be capable of continuous operation but must also be capable of being commanded Off or to a lower power mode before being restabilized thermally for more data taking. Science and engineering data will be transferred to the spacecraft for on-board storage and then transmitted to the ground station. A mission duration of 2 years is planned.

1.3 Scientific Objectives

The SABER instrument shall be designed to measure (1) the global temperature and density structure; (2) the abundance of chemically and radiatively active trace gases; (3) the role of dynamics in influencing atmospheric structure; (4) coupling between these processes and atmospheric regions; and (5) polar processes during both summer and winter. These measurements promise to yield significant scientific returns. A summary of parameters that will be measured by SABER and their application to these studies is shown in Table 2. Data from all channels will be taken for the adaptive scan sequence (0-200 km altitude) and during calibration scans to 400 km.

Table 2. SABER Measurements and Applications

Parameter	Filter 5% Relative Transmission Limits (cm^{-1})	Geophysical Information / Application	Altitude Range (km)
CO_2	580-760	Kinetic temperature; infrared cooling rates; altitude/ pressure registration; non-LTE/LTE nature of CO_2	10-120
	580-760		
	650-695		
O_3	1010-1140	Ozone concentration; cooling rates; solar heating rates; fundamental chemistry and dynamics studies	15-100
$O_2(^1\Delta)$	7730-7970	O_3 concentration; energy loss; inferred atomic oxygen	50-105
CO_2	2320-2400	CO_2 concentration above 85-150 km; upper mesospheric solar heating; dynamical tracer above approximately 90 km	85-150
OH(υ)	4500-5200	Emission used to infer [H], [O]; chemiluminescent energy loss; dynamics/wave studies; polar mesospheric cloud studies	80-100
	5740-6435		
NO	1865-1930	Thermospheric cooling; dynamical tracer, NOx chemistry	90-180
H_2O	1380-1560	Odd-hydrogen source gas; dynamical tracer	15-80

1.4 Instrument Technical Approach

The experiment technique is inversion of thermal Earth limb emission profiles measured by an infrared multispectral radiometer covering the range from 1.25 to 17.2 μm (7970 to 580 cm^{-1}). Because thermal emission is being observed, measurements will be made both night and day. SABER science measurement requirements are listed in Table 3.

The scientific requirement for high vertical resolution is met with a 2 km instantaneous vertical field of view. CO_2 channels will be used for the crucial temperature observations. SABER will also use these CO_2 channels to define the scan altitude pressure registration and to accurately derive spacecraft motion for use in data correction. An in-flight calibration system will provide long-term precision.

A set of detectors will be designed, mounted and thermally conditioned, as necessary, to provide the sensitivity needed to measure the selected species in the mesosphere and lower thermosphere. Filters (narrowband and broadband) will be incorporated in the detector assembly design (as appropriate) to enhance data accuracy.

The on-board instrument controller will be programmed to minimize required ground commands. For example, a single command may permit the instrument to proceed autonomously through the warm-up and calibrate modes and into the data collection mode.

Table 3. SABER Science Measurement Requirements

Parameter	Measurement Requirement
Spectral resolution	Broadband radiometer, 45 to 700 cm^{-1}, depending on the channel
Focal plane channel location	See Figure 3
Filter characteristics	See Table 4
System noise equivalent radiance (NEN)	See Table 4
Flight data calibration: Radiometric accuracy Long term radiometric precision Radiance bias drift Residual scale error	Systematic errors shall not exceed the following after all calibration corrections are applied: 5.0% absolute radiance; 3% goal* 2.0% radiance precision; 1% goal* ≤1 NEN between space looks ≤1% linearity over dynamic range*
IFOV @ 60 km Earth limb tangent height	2 km FWHM
Limb scan mirror jitter	3 arcsec (1 σ)
Limb vertical sampling interval	0.4 km
Along-measurement-track latitude resolution	≤5°
Limb vertical-scan-angle range	See Table 5
Measurement altitude range	10 to 180 km

* For SNR>100, % is defined as a percentage of the signal. For SNR≤100, % is defined as a percentage of the signal that produces SNR=100.

Table 4. SABER Channel Spectral Response

Ch	Species	Center Wavelength (cm^{-1})	Center Wavelength (μm)	Spectral Bandpass (cm^{-1})	Filter 5% Relative Transmission Limits (cm^{-1})	Filter Out-of-Band Rejection Ratio	System NEN [+] (W/cm^2-sr)	Dynamic Range
1	CO_2 (N)	673	14.9	45	650 - 695	$<10^{-4}$	17.5×10^{-9}	15000
2	CO_2 (W)	670	14.9	180	580 - 760	$<10^{-3}$	28×10^{-9}	36000
3	CO_2 (W)	670	14.9	180	580 - 760	$<10^{-3}$	28×10^{-9}	36000
4	O_3	1075	9.3	130	1010 - 1140	$<5 \times 10^{-4}$	11.2×10^{-9}	51000
5	H_2O	1470	6.8	180	1380 - 1560	$<10^{-4}$	3.73×10^{-9}	13000
6	NO	1898	5.3	65	1865 - 1930	$<10^{-4}$	2.49×10^{-9}	82000
7	CO_2	2360	4.2	80	2320 - 2400	$<10^{-4}$	1.32×10^{-9}	1200
8	OH (A)	4850	2.1	700	4500 - 5200	$<10^{-4}$	0.47×10^{-9}	530000
9	OH (B)	6088	1.6	695	5740 - 6435	$<10^{-4}$	0.7×10^{-9}	670000
10	O_2	7850	1.3	240	7730 - 7970	$<10^{-4}$	0.7×10^{-9}	310000

[+] For 0.110 second integration time.

Table 5. SABER Scan Angle Requirements

Scan Angle	Scan Range
Maximum depression angle	Angle required to place the top edge of the FPA at a tangent altitude 3 km below the horizon
Minimum depression angle	Angle required to place the bottom edge of the FPA at a tangent altitude of 400 km

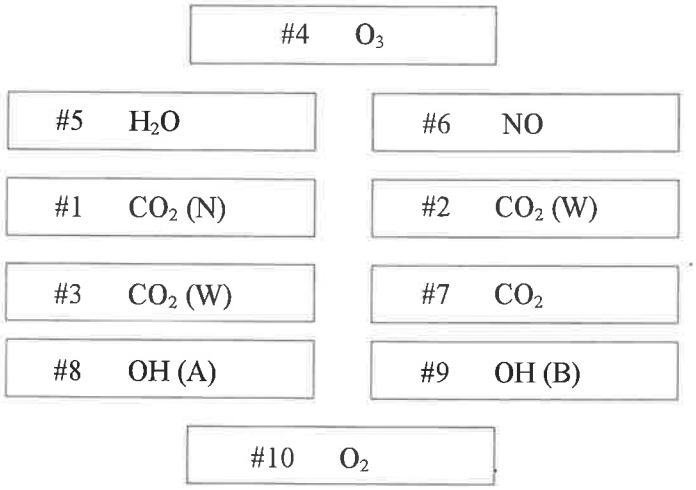


Figure 3. SABER Focal Plane Array Channel Location

2. SCIENCE PERFORMANCE REQUIREMENTS

The SABER instrument shall make the following measurements, within the prescribed parameters.

2.1 General

2.1.1 The SABER instrument shall make all measurements with a residual scale error of <1% of linearity over dynamic range.

2.2 Carbon Dioxide CO_2

2.2.1 14.9 μm Narrowband CO_2 [CO_2 (N)]

2.2.1.1 The SABER instrument shall measure narrowband CO_2 emission in the altitude range of 10 to 120 km.

2.2.1.2 The SABER instrument shall measure narrowband CO_2 emission with 5% relative transmission filter limits of 650 to 695 cm^{-1}.

2.2.1.3 The SABER instrument shall measure narrowband CO_2 emission with a radiance bias error of $\leq 17.5\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.2.2 14.9 μm Broadband CO_2 [CO_2 (W)]

2.2.2.1 The SABER instrument shall measure broadband CO_2 emission in the altitude range of 10 to 120 km.

2.2.2.2 The SABER instrument shall measure broadband CO_2 emission with 5% relative transmission filter limits of 580 to 760 cm^{-1}.

2.2.2.3 The SABER instrument shall measure broadband CO_2 emission with a radiance bias error of $\leq 28.0\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.2.3 Additional 14.9 μm Broadband CO_2 [CO_2 (W)]

2.2.3.1 The SABER instrument shall make an additional broadband CO_2 emission measurement in the altitude range of 10 to 120 km.

2.2.3.2 The SABER instrument shall make an additional broadband CO_2 emission measurement with 5% relative transmission filter limits of 580 to 760 cm^{-1}.

2.2.3.3 The SABER instrument shall make an additional broadband CO_2 emission measurement with a radiance bias error of $\leq 28\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.2.4 4.2 μm Broadband CO_2

2.2.4.1 The SABER instrument shall measure 4.2 μm CO_2 emission in the altitude range of 85 to 150 km.

2.2.4.2 The SABER instrument shall measure 4.2 μm CO_2 emission with 5% relative transmission filter limits of 2320 to 2400 cm^{-1}.

2.2.4.3 The SABER instrument shall measure 4.2 μm CO_2 emission with a radiance bias error of $\leq 1.32\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.3 6.8 μm Water [H_2O]

2.3.1 The SABER instrument shall measure H_2O emission in the altitude range of 15 to 80 km.

2.3.2 The SABER instrument shall measure H_2O emission with 5% relative transmission filter limits of 1380 to 1560 cm^{-1}.

2.3.3 The SABER instrument shall measure H_2O emission with a radiance bias error of $\leq 3.73\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.4 9.3 μm O_3 [O_3]

2.4.1 The SABER instrument shall measure O_3 emission in the altitude range of 15 to 100 km.

2.4.2 The SABER instrument shall measure O_3 emission with 5% relative transmission filter limits of 1010 to 1140 cm^{-1}.

2.4.3 The SABER instrument shall measure O_3 emission with a radiance bias error of $\leq 11.2\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.5 1.3 μm $O_2(^1\Delta)$ [O_2]

2.5.1 The SABER instrument shall measure $O_2(^1\Delta)$ emission in the altitude range of 50 to 105 km.

2.5.2 The SABER instrument shall measure $O_2(^1\Delta)$ emission with 5% relative transmission filter limits of 7730 to 7970 cm^{-1}.

2.5.3 The SABER instrument shall measure $O_2(^1\Delta)$ emission with a radiance bias error of $\leq 0.70\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.6 5.3 μm NO [NO]

2.6.1 The SABER instrument shall measure NO emission in the altitude range of 90 to 180 km.

2.6.2 The SABER instrument shall measure NO emission with 5% relative transmission filter limits of 1865 to 1930 cm^{-1}.

2.6.3 The SABER instrument shall measure NO emission with a radiance bias error of $\leq 2.49\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.7 2.1 μm OH(υ=7,8,9) [OH (A)]

2.7.1 The SABER instrument shall measure OH(υ=7,8,9) emission in the altitude range of 80 to 100 km.

2.7.2 The SABER instrument shall measure OH(υ=7,8,9) emission with 5% relative transmission filter limits of 4500 to 5200 cm^{-1}.

2.7.3 The SABER instrument shall measure OH(υ=7,8,9) emission with a radiance bias error of $\leq 0.47\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

2.8 1.6 μm OH(υ=3,4,5) [OH (B)]

2.8.1 The SABER instrument shall measure OH(υ=3,4,5) emission in the altitude range of 80 to 100 km.

2.8.2 The SABER instrument shall measure OH(υ=3,4,5) emission with 5% relative transmission filter limits of 5740 to 6435 cm^{-1}.

2.8.3 The SABER instrument shall measure OH(υ=3,4,5) emission with a radiance bias error of $\leq 0.7\ (10)^{-9}$ W/cm^2-sr (or 1 NEN).

3. INSTRUMENT OPERATIONAL REQUIREMENTS

3.1 Spatial

3.1.1 The SABER instrument shall provide for a vertical IFOV of 2 km FWHM at 60 km Earth limb tangent height for a 600 km spacecraft altitude.

3.1.2 The SABER instrument shall provide a limb vertical scan range in accordance with Table 5.

3.1.3 The SABER instrument shall provide for one complete scan and calibration sequence within each 75 second interval.

3.1.4 The SABER instrument shall provide for a continuous limb vertical scan with data points recorded every 0.4 km.

3.2 Calibration

3.2.1 The SABER instrument shall provide for viewing of cold space to verify offsets.

3.2.2 The SABER instrument shall provide necessary in-flight calibration sources to ensure the 1% residual scale error linearity requirement.

3.3 Data Processing

3.3.1 The SABER instrument shall provide for the upload and storage of instrument command programs.

3.3.2 The SABER instrument shall provide for acquisition and formatting of science and housekeeping data.

3.3.3 The SABER instrument shall provide for adequate onboard memory storage.

3.3.4 The SABER instrument shall provide for preprocessing and formatting of radiometric data.

4. DESIGN CONSTRAINTS

4.1 General

4.1.1 The design shall provide for an instrument mission operational life of 17500 hours.

4.1.2 The SABER instrument shall provide for a 1 σ limb scan mirror jitter of less than 3 arcsec.

4.2 Pointing

4.2.1 The SABER instrument shall make the science measurements of Section 2 while requiring a spacecraft pointing accuracy of less than 1° ($3\ \sigma$).

4.2.2 The SABER instrument shall require a spacecraft pointing knowledge of less than 0.1°.

4.2.3 The SABER instrument shall require a spacecraft drift stability of less than 0.0075°/sec over 18 sec.

4.2.4 The SABER instrument shall make the measurements of Section 3 given a spacecraft jitter of up to 20 arcsec.