CR-189430

GUVI GUVI FINAL REPORT

FINAL REPORT

NASA CONTRACT NO. NAS5-32572

GLOBAL ULTRAVIOLET IMAGER
(GUVI) INVESTIGATION

PERIOD OF PERFORMANCE
08 NOV 1993 THROUGH 07 DEC 1994

SUBMITTED BY

THE AEROSPACE CORP.
SPACE AND ENVIRONMENT TECHNOLOGY CENTER
P.O. BOX 92957
LOS ANGELES, CA 90009

PRINCIPAL INVESTIGATOR

ANDREW B CHRISTENSEN

(NASA-CR-189430) GLOBAL ULTRAVIOLET IMAGER (GUVI) INVESTIGATION Final Report, 8 Nov. 1993 - 7 Dec. 1994 (Aerospace Corp.) 106 p

N95-31820

Unclas

G3/46 0058476

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GUVI INVESTIGATOR TEAM

Principal Investigator: Andrew B. Christensen
Principal Director
Space and Environment Technology Center
The Aerospace Corporation

R. L Walterscheid
M. N. Ross

Space and Environment Technology Center
The Aerospace Corporation

C. -I. Meng
L. J. Paxton
D. E. Anderson
G. Crowley

Applied Physics Laboratory
The Johns Hopkins University

S. Avery
Department of Engineering
University of Colorado

J. D. Craven

Geophysical Institute and Dept. of Physics
University of Alaska Fairbanks

R. R. Meier

E. O. Hulburt Center for Space Research,
Naval Research laboratory

D. J. Strickland

Computational Physics, Inc.

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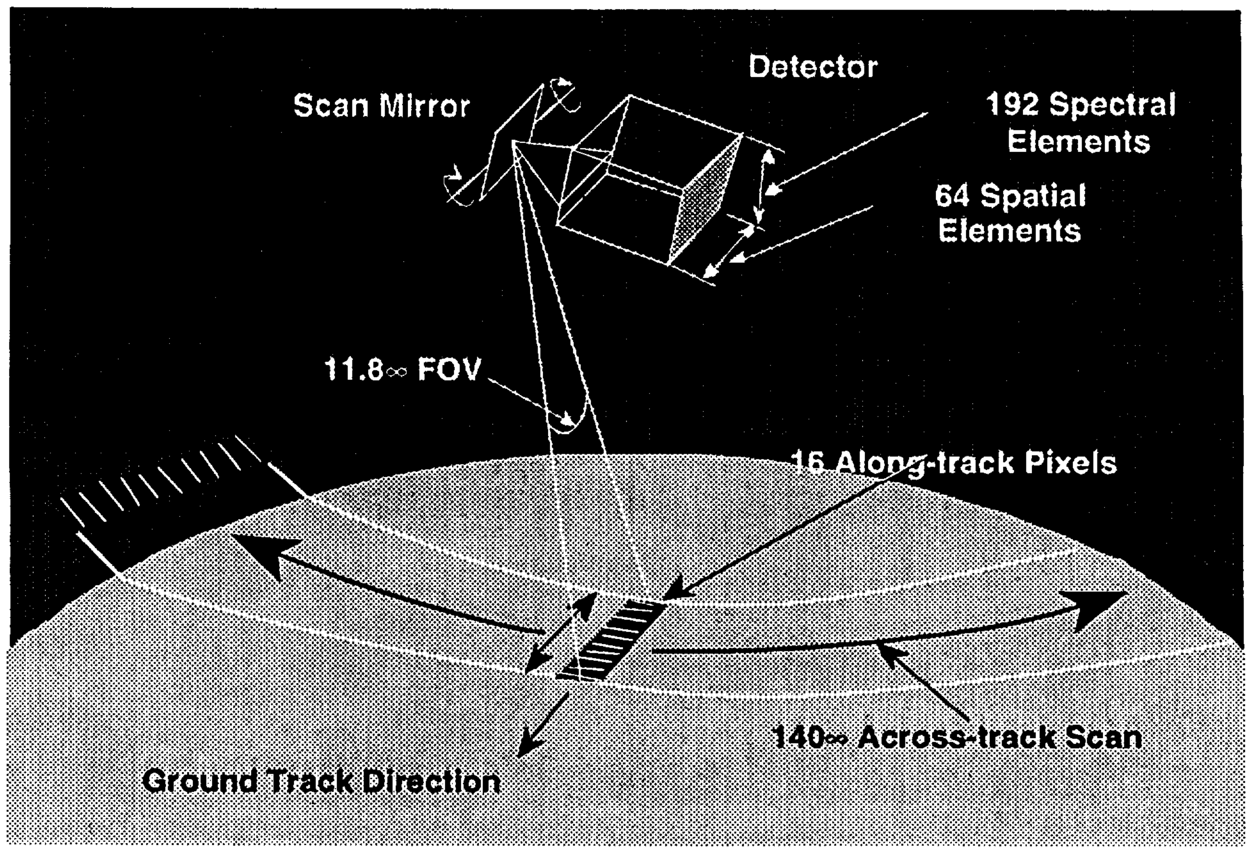
- Ground state transitions for N_2, O, and H are located in the far ultraviolet (110-180 nm)
- Radiation is absorbed below ~ 100 km providing black background and no albedo
- Well developed models of excitation and radiation transport to extract geophysical quantities from the measured UV radiances
- Instrumental techniques mature
- Principle emission features

  HI(121.6)
  OI(130.4)
  OI(135.6)
  N_2LBH(130-180)

GUVI IMAGING TECHNIQUE



- TIMED SCIENCE OBJECTIVES

  (1) To determine the temperature, density, and wind structure of the MLTI, including the seasonal and latitudinal variations.

  (2) To determine the relative importance of the various radiative, chemical, electrodynamical, and dynamical sources and sinks of energy for the thermal structure of the MLTI.

- GUVI SCIENCE GOALS

  (1) Determine the spatial and temporal variations of temperature and constituent densities in the lower thermosphere.

  (2) Determine the importance of auroral energy sources and solar EUV to the energy balance of the region

- **Dayside**
  - Constituent Densities: N_2, O_2, O, H
  - Solar EUV Flux: Integral $\lambda \leq 40$ nm
- **Auroral Regions**
  - Particle Energy Input
  - Joule Heating
  - Auroral Boundaries
- **Nightside**
  - F-Region Height, Peak Density
  - Total Electron Content
  - Meridional Winds
  - RING CURRENT PRECIPITATION

- Validate the general circulation models of the LTI region combining observations of
  - Solar EUV
  - Winds
  - Auroral energy inputs
  - Compositon
  - NO cooling
- Investigate compositional signatures of tidal and planetary wave structures in conjunction with wind observations from TIDI, including seasonal and latitudinal dependencies.
- Examine the relationships between meso-scale and large scale compositional structure and perturbations vertically and horizontally.
- Investigate the relationships between compositional variations (spatially and temporally) and prior heating from both solar EUV and auroral sources. Track the evolution of magnetic storm-induced perturbations in the LTI system.

- **Investigate the cell structure in the high latitude neutral mass density predicted by the NCAR-TIGCM.**

- **Determine the importance of auroral and solar heat sources to the thermal structure of the MLTI.**

- **Provide data for updating empirical models such as MSIS for high levels of forcing, both solar and geomagnetic.**

- **Investigate the properties of the equatorial meridional wind system deduced from optical observations of inter-tropical arcs.**

- **Cross calibrate the ~~composition measurements and~~ integrated solar EUV flux derived from GUVI with ~~occultation and~~ EUV measurements using the SEE instrument~~, respectively~~.**

- **Study the occurance, structure, and distribution of Polar Mesospheric Clouds.**

TABLE 5 *SCIENCE DRIVEN MEASUREMENT GOALS FOR THE GUVI EXPERIMENT.*

Environmental Parameter	Altitude Range	Accuracy	Spatial Scales	Temporal Scales
ENERGETICS				
Energetic Particles	90 -180 km	Flux 20%[1]	20 km	10 min
Solar EUV flux (<40 nm)	>300 km	10%[2]	Broad-band Proxy*	10 / day
Pedersen and Hall Conductivities	100-200 km	20%[3]	100 km	10 min
DYNAMICS				
Tides and Planetary Waves	95±4 km* 130-400 km	DI/I < 1%[a]	100 km	1.5 hr
Intertropical Meridional Winds	F-region	20%[4]	100 km	1.5 hr
STATE VARIABLES				
Major Species Abundance (O, N_2, O_2)	130-400 km*	5-10%	1/2 Scale Height (Vertical) 100 km (Horiz. for Tides and Planetary Waves)	1.5 hrs (Tides and Planetary Waves) 1 Month (Seasonal)
Minor Species (H)	130-400 km*	5-10%[5]	1/2 Scale Height (Vertical) 100 km (Horiz. for Tides and Planetary Waves)	1.5 hrs (Tides and Planetary Waves) < 1 Month and Seasonal
Charged Species (N_e, O^+)	E and F region*	10%[4]	1/2 Scale Height (Vertical) 10 km(Horiz.)	1.5 hr*
Neutral Temperature	130-400 km*	5%[4]	1/2 Scale Height* 100 km (Tides and Planetary Waves)	1.5 hr (Tides and Planetary Waves) < 1 Month and Seasonal

1 Optical technique demonstrated by *Hecht et al.* [1989]
2 *Strickland et al.* [1983]
3 *Lummerzheim et al.* [1991]
4 Appendix A.
5 *Anderson et al.* [1987]
* Subset of the TIMED Vol. III (Table I.2.4)
a Derived quantities not explicitly specified in the TIMED goals table.

GUVI MEASUREMENTS APPROACH

Brightness Measurements on Disk and Limb of atomic and molecular emission excited by photoelectron impact. Images in five colors:

- **HI(121.5)**
- **OI(135.6)**
- **OI(130.4)**
- **LBH(140-150 nm)**
- **LBH(165-180 nm)**

MEASUREMENTS APPROACH (cont)

The radiances are measured with sufficient accuracy and precision to infer changes in the state variables:

- Temp, O_2, O, N_2, H, O/N_2 column, Nmax, TEC

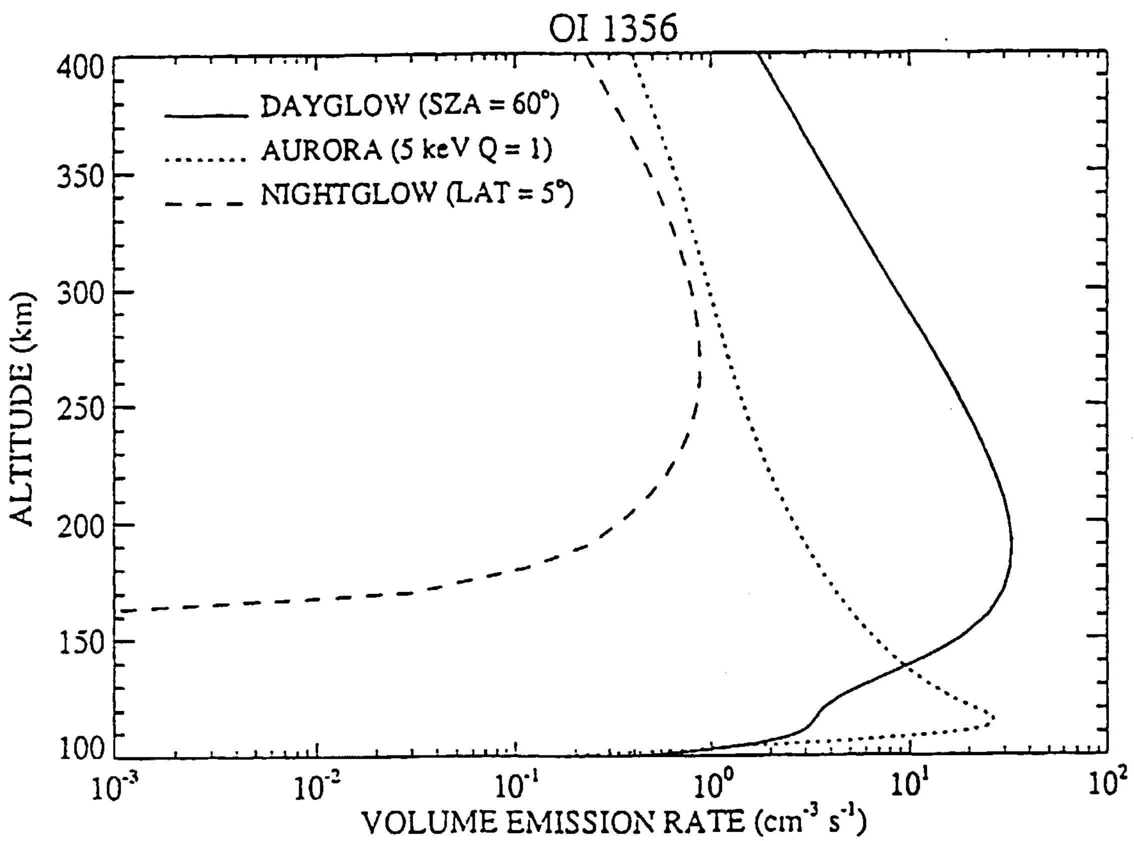
values of auroral quantities:

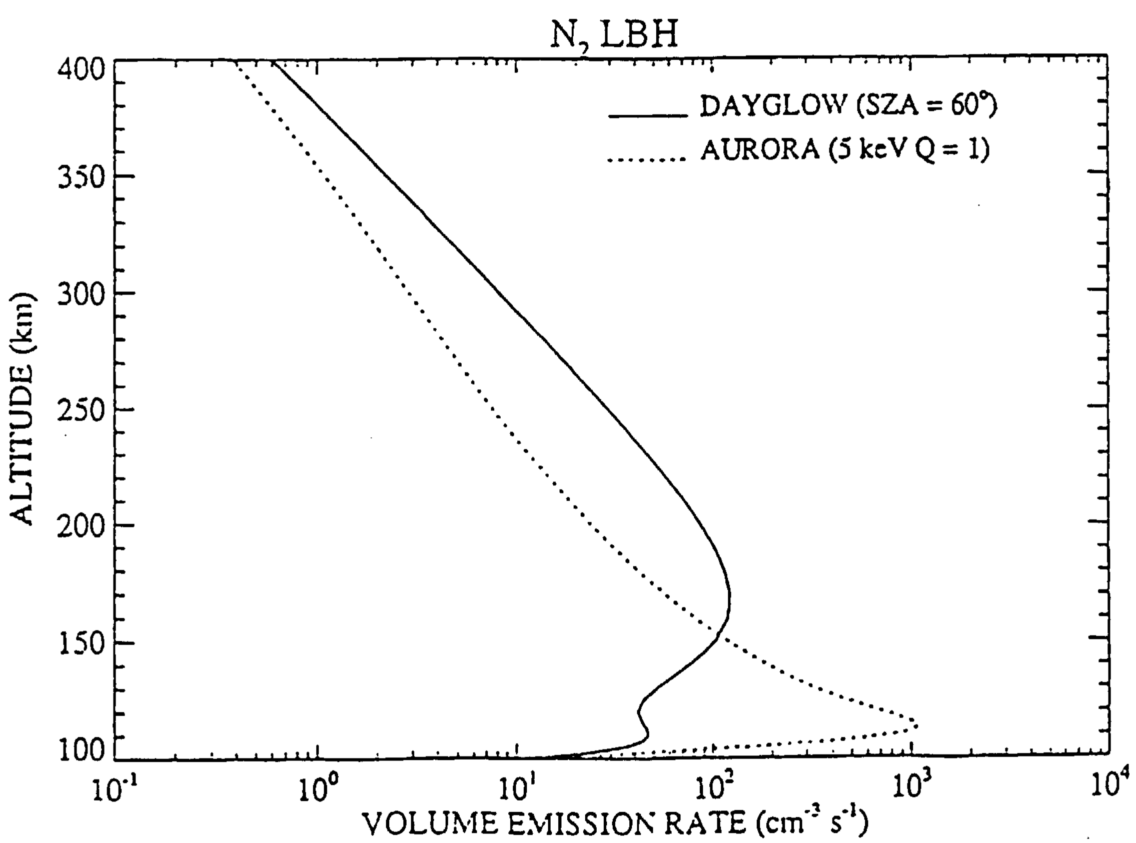
- Q_e, Q_p, E_o, Σ_p

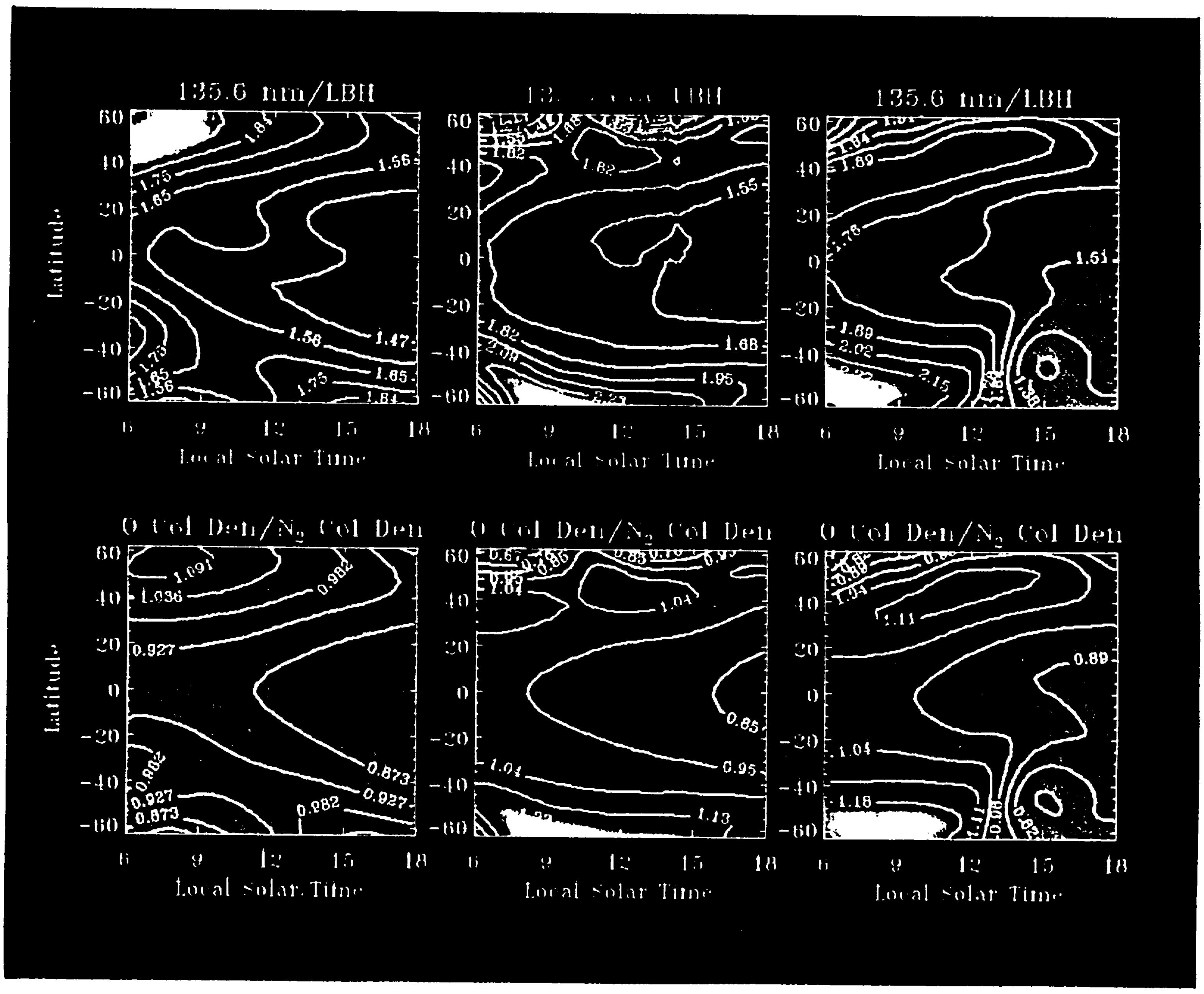
and solar EUV Flux (wavelength < 40 nm)

The images are analyzed for scientific study of:

- Thermospheric composition and temperature
- Auroral energy inputs
- Solar EUV integrated flux
- Low-latitude ionosphere at night


OI 1356
DAYGLOW (SZA = 60°)
AURORA (5 keV Q = 1)
NIGHTGLOW (LAT = 5°)
ALTITUDE (km)
VOLUME EMISSION RATE (cm⁻³ s⁻¹)


N₂ LBH
DAYGLOW (SZA = 60°)
AURORA (5 keV Q = 1)
ALTITUDE (km)
VOLUME EMISSION RATE (cm⁻³ s⁻¹)


135.6 nm/LBH
135.6 nm/LBH
O Col Den/N2 Col Den
O Col Den/N2 Col Den
O Col Den/N2 Col Den
Latitude
Local Solar Time

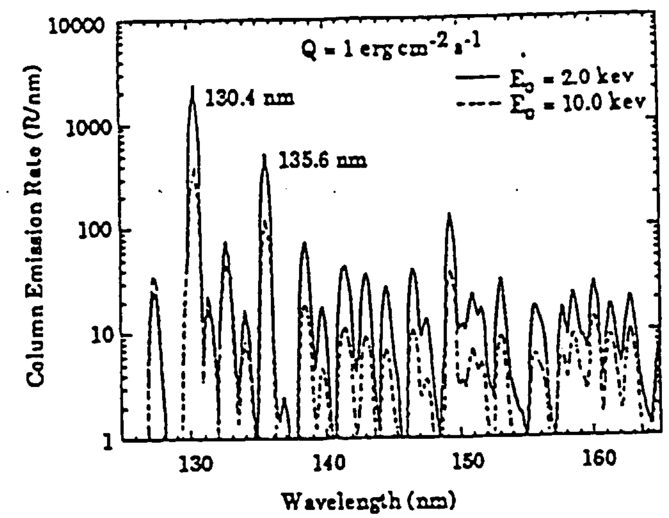


Figure 12. Calculated auroral N_2 and O spectrum.

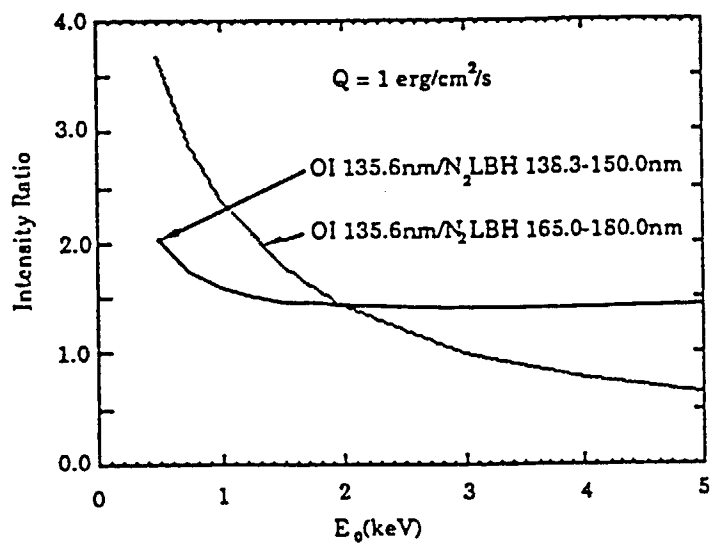


Figure 13. Auroral characteristic energy versus OI (135.6 nm) / N_2 LBH ratio using two different N_2 LBH wavelength bands.

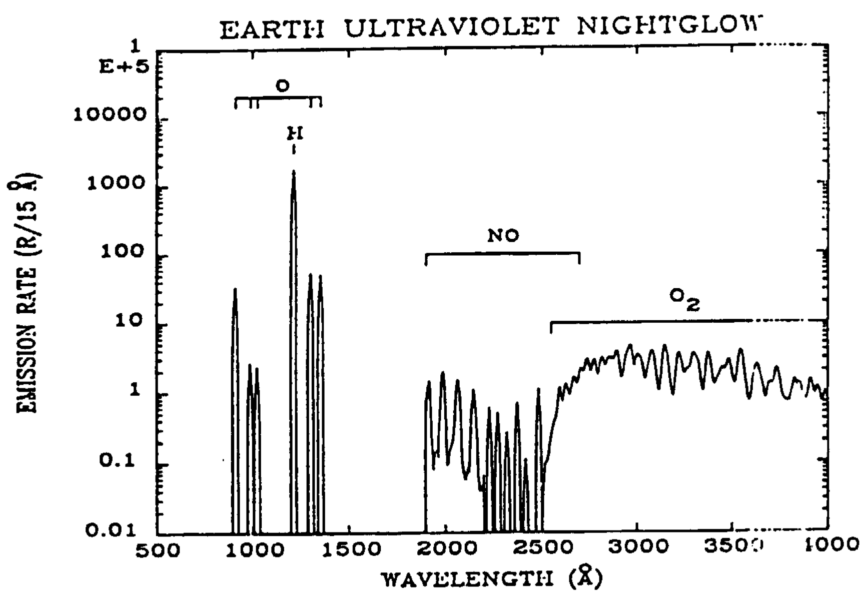


Fig. 9. Composite UV nightglow spectrum adjusted to nadir viewing from 600 km in equatorial region. All spectral features have been smoothed to 15 Å resolution. The O_2 and NO molecular, the H geocoronal resonant scattering, and the $O^+ + e \rightarrow O$ recombination emissions are indicated. The O_2 spectrum was taken from the Hennes (1966) rocket experiment, the NO spectrum from the Sharp and Rusch (1981) rocket data, and the O I and H I lines from the STP 78-1 satellite data of Chakrabarti *et al.* (1984). The absolute values of the O_2 and NO bands were obtained by normalizing to the Huffman *et al.* (1980) S3-4 equatorial spectrum (after converting the S3-4 data to absolute units). The nightglow varies strongly with geographic position, local time, and solar activity.

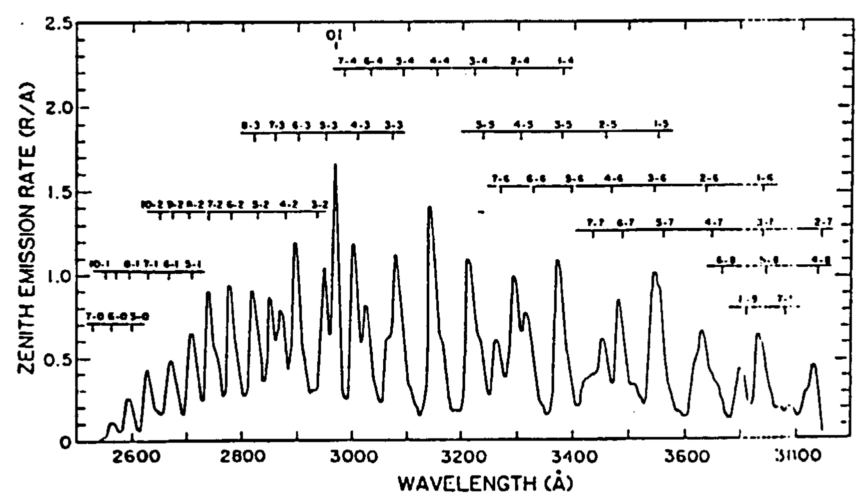


Fig. 10. MUV and NUV spectra at 12 Å resolution obtained on 30 November, 1964 from a horizontally viewing rocket experiment at 184 km (after Hennes, 1966). The O_2 Herzberg I band identifications were taken from Degen (1969). The intensity scale was obtained after adjustment to zenith by Hennes, giving 600 *R* in the Herzberg I band. The O I line at 2973 Å is indicated at the top.

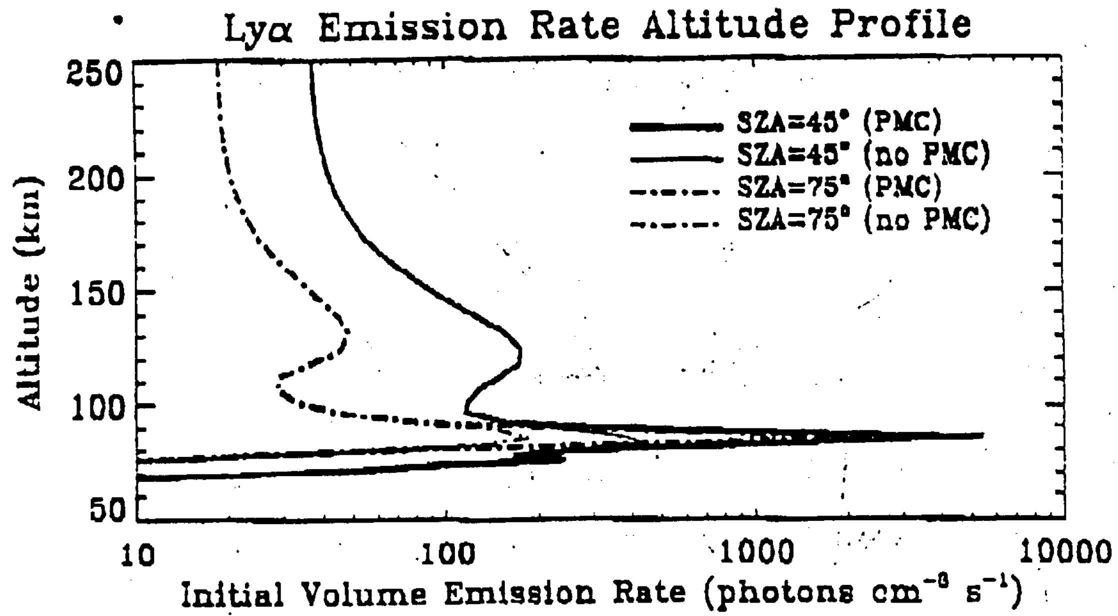


Fig. 3 Estimated Lyα volume emission rates for geocorona and a PMC (thick lines) and geocorona alone (thin curves). Results are shown for two solar zenith angles; 45° (solid lines) and 75° (dot-dash lines). The presence of a PMC enhances the initial emission rate by a factor of ~20 at 85 km. The interesting vertical structure above 90 km is explained in the text.

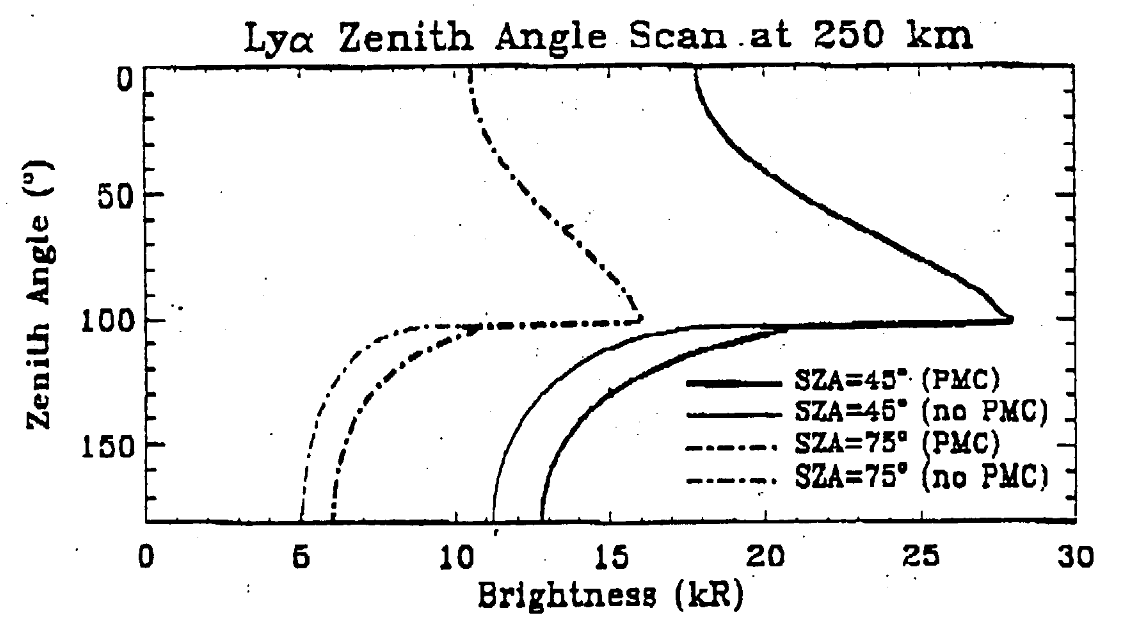
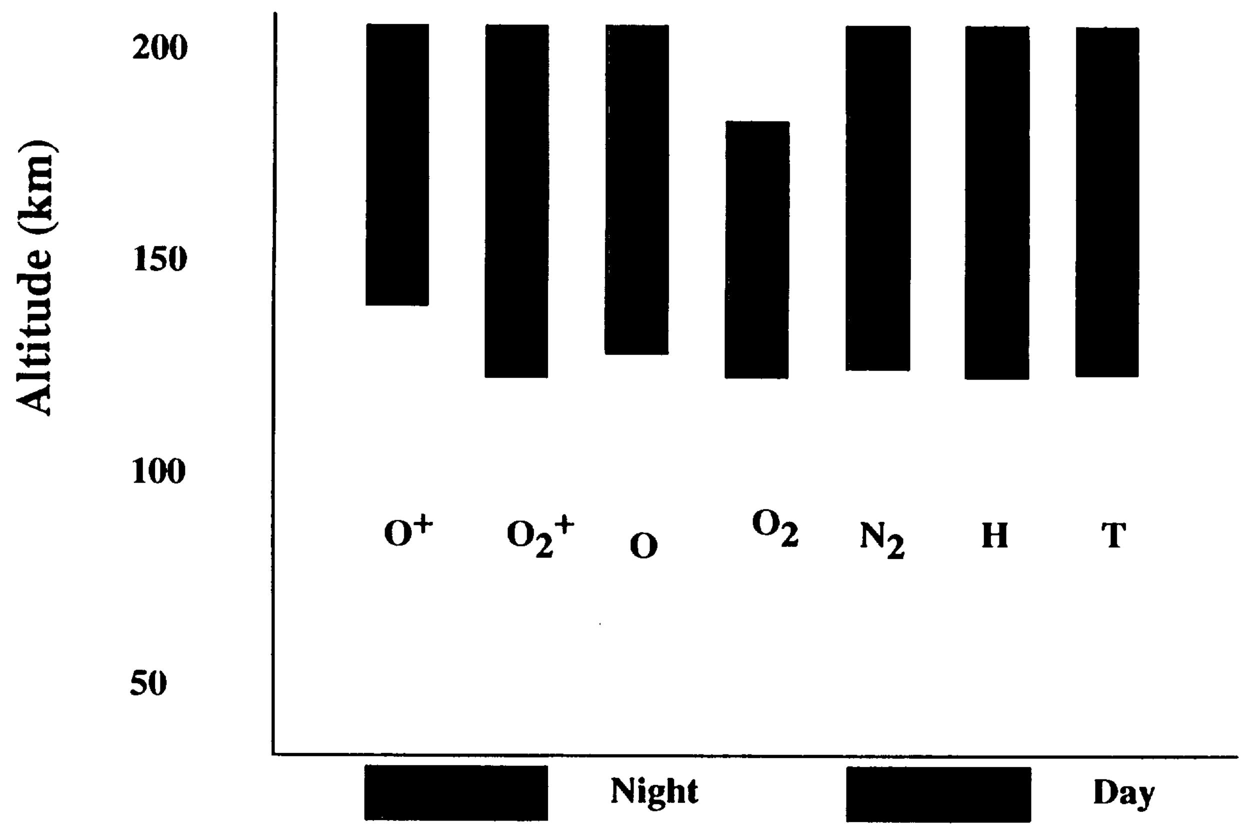


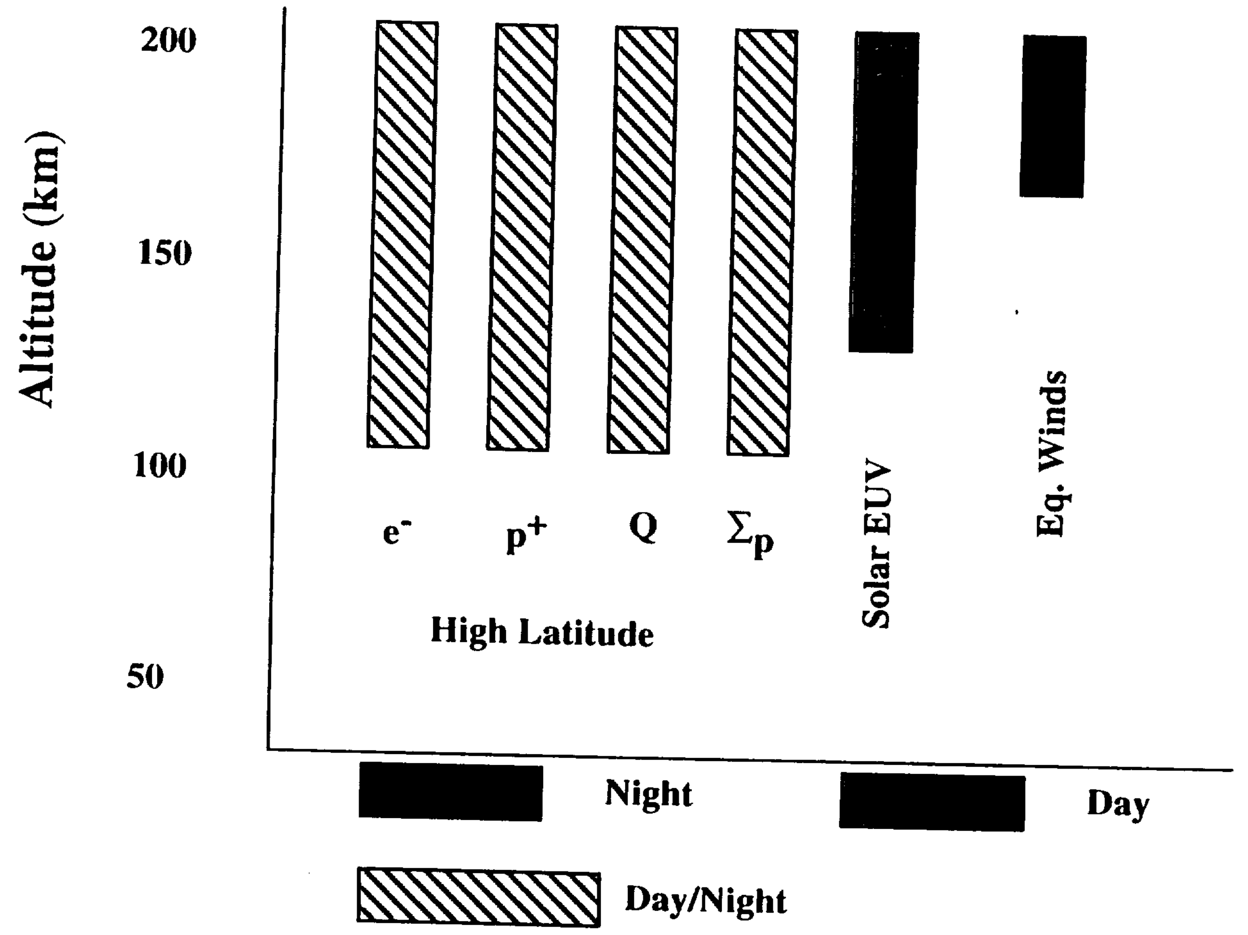
Fig. 4 Estimated brightness as a function of look-direction zenith angle, from an altitude of 250 km. The same cases are shown as described in Fig. 3, and the results indicate that the presence of a PMC could enhance the observed Lyα brightness by 15–25%.

Fig. 3 GUVI DERIVED STATE VARIABLES



Altitude range for atmospheric state variables derived from GUVI observations.

Fig. 4 GUVI DERIVED ENERGY AND DYNAMICAL QUANTITIES



Altitude range for energy and dynamical quantities derived from GUVI observations. Q is the energy flux of precipitationg auroral particles, Σ_p is height-integrated Pedersen conductivity, e^- and p^+ are fluxes of electrons and protons.

SPATIAL REQUIREMENTS SUMMARY

Altitude Resolution on Limb	:	**IFOV:0.37° /15 km, Spacing: 0.5°/20 km,@ 600 km orbital altitude**
Altitude Coverage on Limb	:	**100 to 500 km**
Spatial Coverage on Disk	:	**Cross Track: IFOV: 0.37°/4 km,140° swath (185 pix, 8 km spacing in nadir), 80° limb to nadir, 60° beyond nadir. Total width 3700 km** **Along Track: IFOV: 11.8°/126 km, 15 pixels (8 km/pix in nadir)**
Spatial Resolution on Disk (Post processing)	:	**Aurora - 20 x 20 km^2** **Dayside - 100 x 100 km^2** **Nightside - 200 X 200 km^2**
Temporal Resolution	:	**Mirror scan time: 13.23s forward, 1.77s flyback, 15 s full scan, 71.5 ms/pix**

MODES

NAME	COLORS	SLIT	SCAN	COMMAND
Mode 0: Dayside	5 wavelength regions	Standard slit, fixed	140° full	Terminator crossing flag needed
Mode 1: Nightside	5 wavelength regions	Wide slit, fixed	140° full	Slit adjustment, and color changes at flag, if requested
Mode 2: Star Calibration	Full wavelength scan	All slits in sequence	Fixed scan mirror, above horizon	Time tagged
Mode 3: Wavelength Calibration	Full wavelength scan	All slits in sequence	Fixed scan mirror, below horizon	Time Tagged
Mode 4: Sun Avoidance	5 wavelength regions	Standard slit, fixed	±60 °	Time Tagged

GUVI LIMB SCAN GEOMETRY

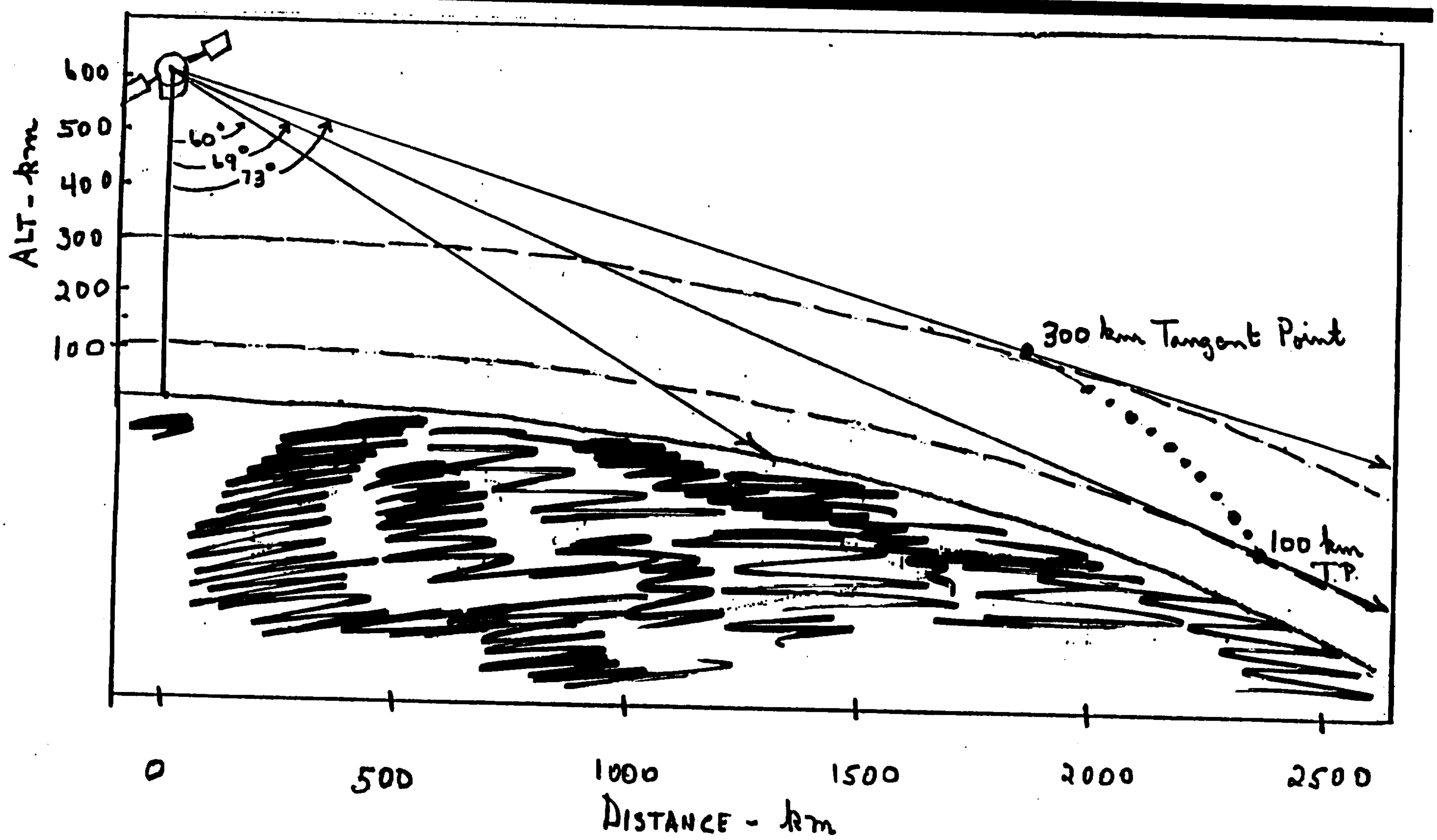


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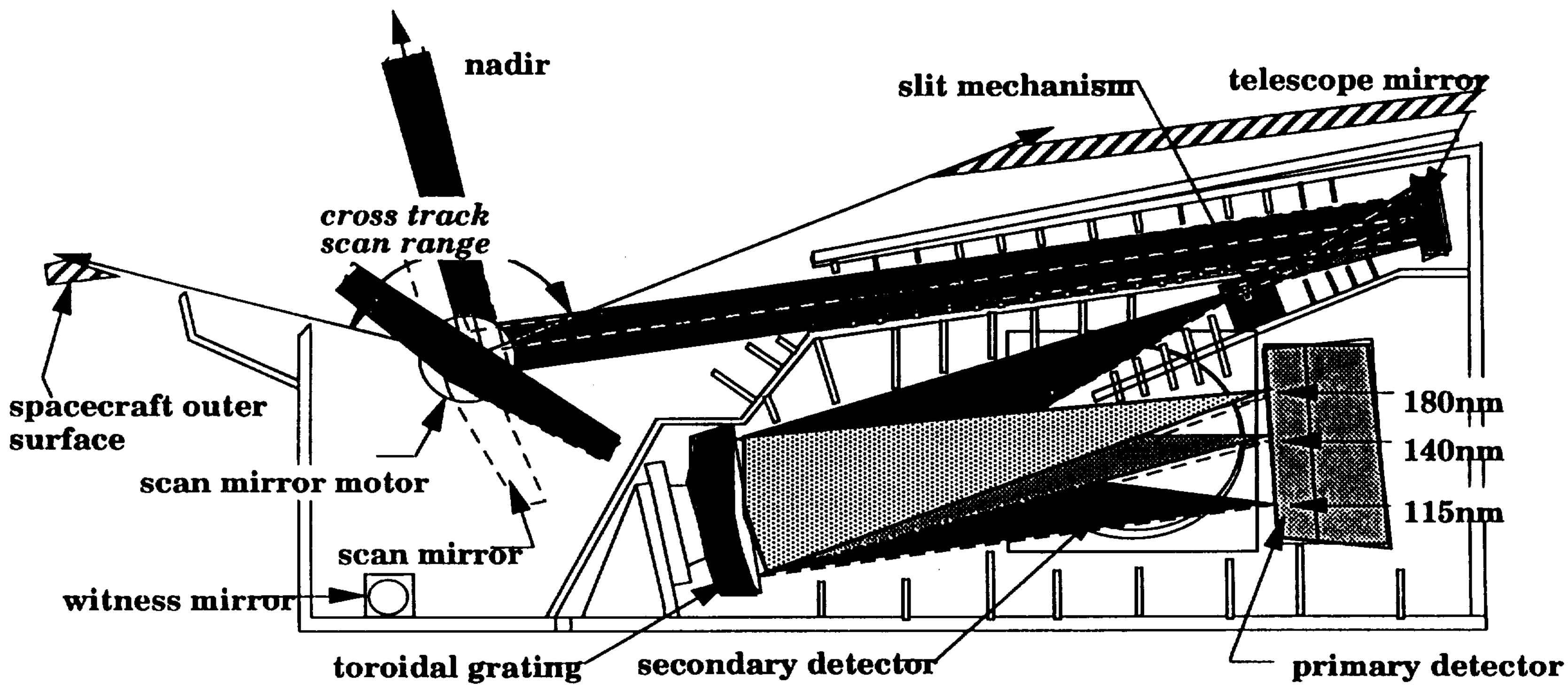
Fig. 6 GUVI LAYOUT DIAGRAM



GUVI layout diagram. The optical components, scan mirror range of motion, slit mechanism, primary and secondary detectors, and spectral dispersion are shown.

GUVI ACCURACY ESTIMATES

DAYSIDE SCIENCE

FEATURES	SPATIAL SCALE	ALTITUDE	PRECISION (view @ 300km, 75° SZA)	INFERRED QUANTITIES	ACCURACY
LIMB					
OI(135.6)		130 - 300 km	± 3 %	N_2,O_2,O	± 15%
LBH (1)	250 km Horizontal		± 7%	Solar EUV	±10-15%
LBH (2)			±10%	Temp	± 8%
HI(121.6)	100 x 100 km²	110 - 300 km	± 1%	H	± 10%
DISK					
OI(135.6)	100 x 100 km²	130 - 300 km	± 3%	$[O]/[N_2]$ column abundance	± 5%
LBH (1)			± 5%		
				$N2,O2,O$	± 20%
HI(121.6)	100 x 100 km²	110 - 300 km	± 1%	H (2 model parameters)	±10%

LOW LATITUDE NIGHTSIDE SCIENCE

FEATURES	SPATIAL SCALE	ALTITUDE	PRECISION	INFERRED QUANTITIES	ACCURACY
OI(135.6) OI(130.4) (radiative recombination emission)	100 X 100 km^2	Lower F Region	± 5%	N_{max}, H_{max} Total Electron Content (TEC)	± 9% ± 22%
OI(130.4) OI(135.6) N_2(LBH) (energetic Particle Precipitation)	100 x 100 km^2	100 - 300 km	± 11%	Energetic Particle Flux	TBD (Cross section uncertainties)

GUVI
ACCURACY ESTIMATES

AURORAL ZONE SCIENCE

FEATURES	SPATIAL SCALE	ALTITUDE	PRECISION (Class II Aurora)	INFERRED QUANTITIES	ACCURACY
OI(135.6)	10 x 10 km^2	100 - 150 KM	± 7 %	Q_e ($Ergs/cm^2/s$)	± 20%
LBH (1)			± 9%	E_o (Kev)	± 25%
LBH (2)			±13%	Σ_P (Mho)	± 30%
HI(121.6)			± 9% *	$Q_{protons}$	± 21%

* 0.1 $ergs/cm^2/s$ proton precipitation flux

GUVI KEY PARAMETERS

LEVEL 2 DATA PRODUCTS

Calibrated and geolocated radiances for nadir and limb scans: dayside, nightside and auroral observations

LEVEL 3 DATA PRODUCTS (Routine)

Dayside

O/N_2
(2-D Maps of column abundance)

ΔN_2, ΔO_2, ΔO, ΔT, ΔH
(Altitude profiles on the limb)

ΔF_{EUV}
(Change in integrated solar flux)

Nightside

n_i
(Altitude profile on limb)

N_{max}, H_{max}
(Along limb track)

TEC
(Line of sight along track)

Auroral (day and night)

Q, E_o
(2-D maps of electron and proton energy fluxes and characteristic energy)

Auroral boundary locations

Σ_p
(2-D maps of height integrated Pedersen conductivity)

n_e in E-layer
(Along track altitude profile)

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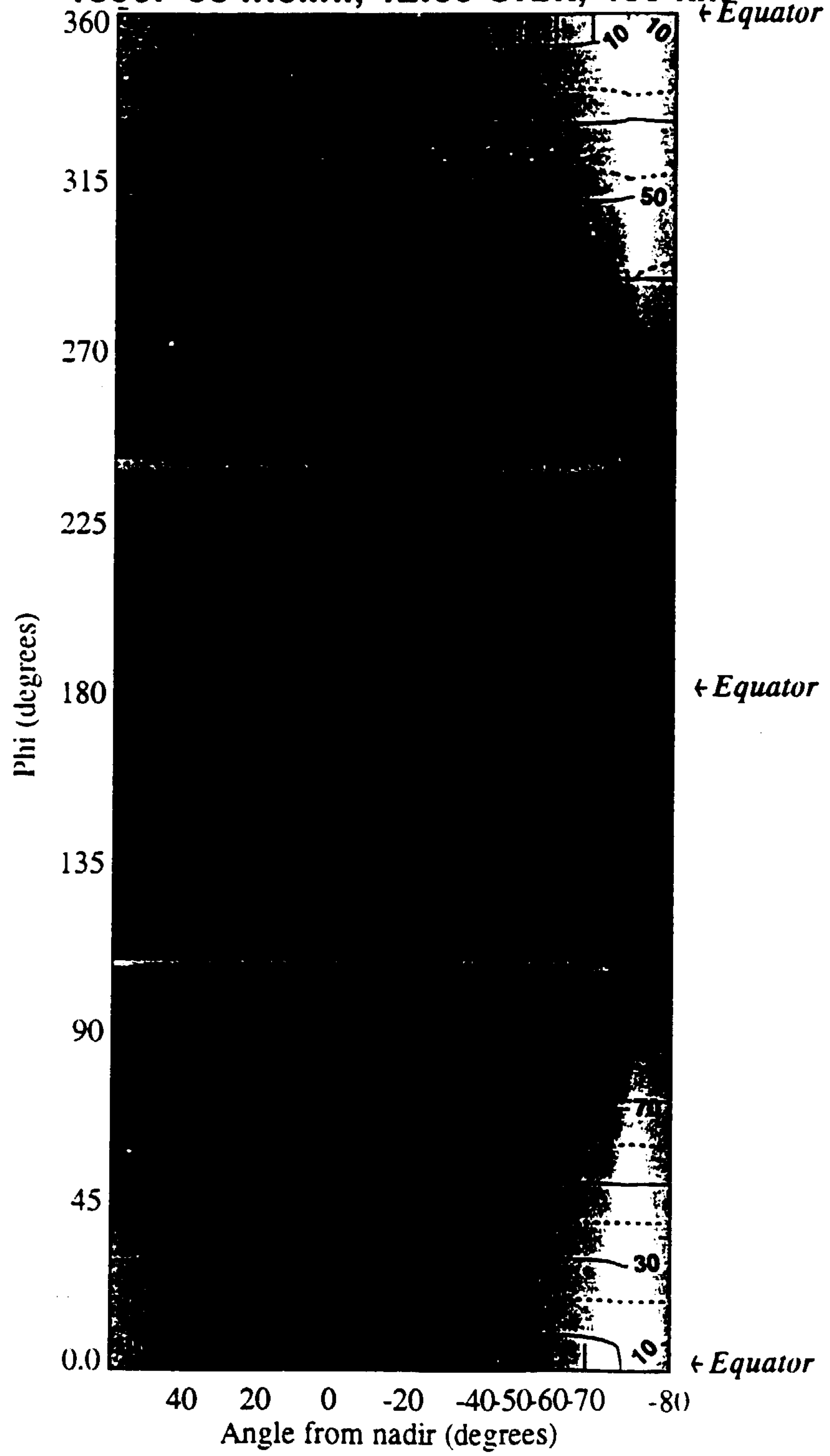
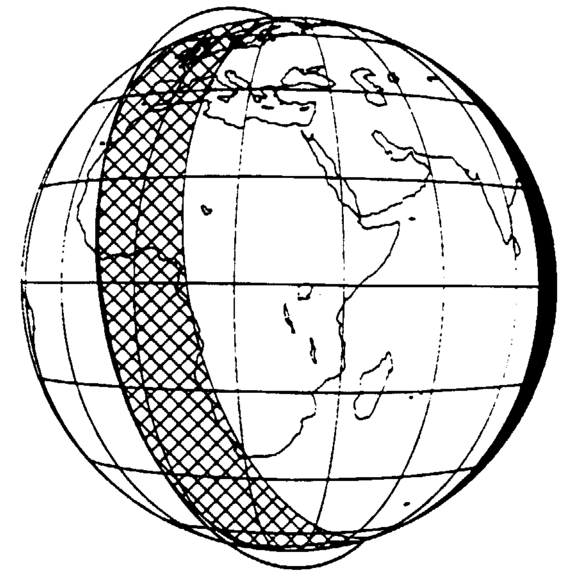
Level 4 Data Products

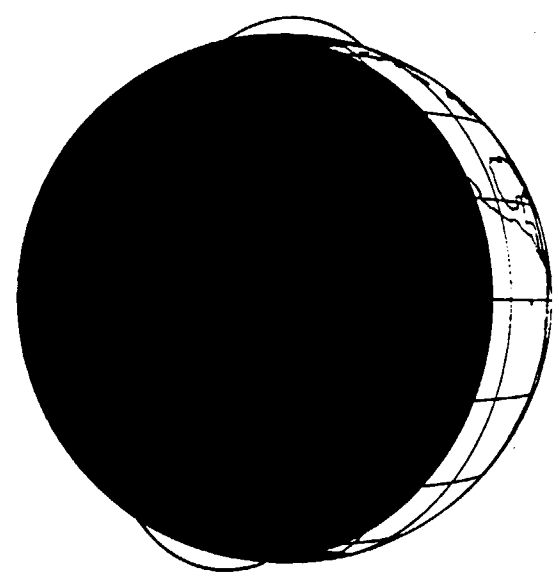
- Compositional signatures of tidal forcing
- Correlations between composition changes and TIDI wind fields associated with magnetic storms
- Joule heating and particle heating rates at high latitudes
- Relationships between compositional variations (spatial and temporal) and heat and momentum source variability
- Derived equatorial meridional F-region wind

1356: 98 Inclin., 12:00 Orbit, 400 km

CPI







CONTAMINATION

Goal: Maintain design goal for sensitivity through end-of life.

Strategy: During I&T purge with research grade N_2.

Keep mirrors clean.
Low-outgassing materials.

No heroic measures are required on the ground.

On orbit:

Protection by a once-only cover blown after the spacecraft has outgassed (~ 2-4 weeks).

No line-of-sight from scan mirror surface to other spacecraft surface.

Avoid prolonged ram operation ($\leq$ 100 hrs?).

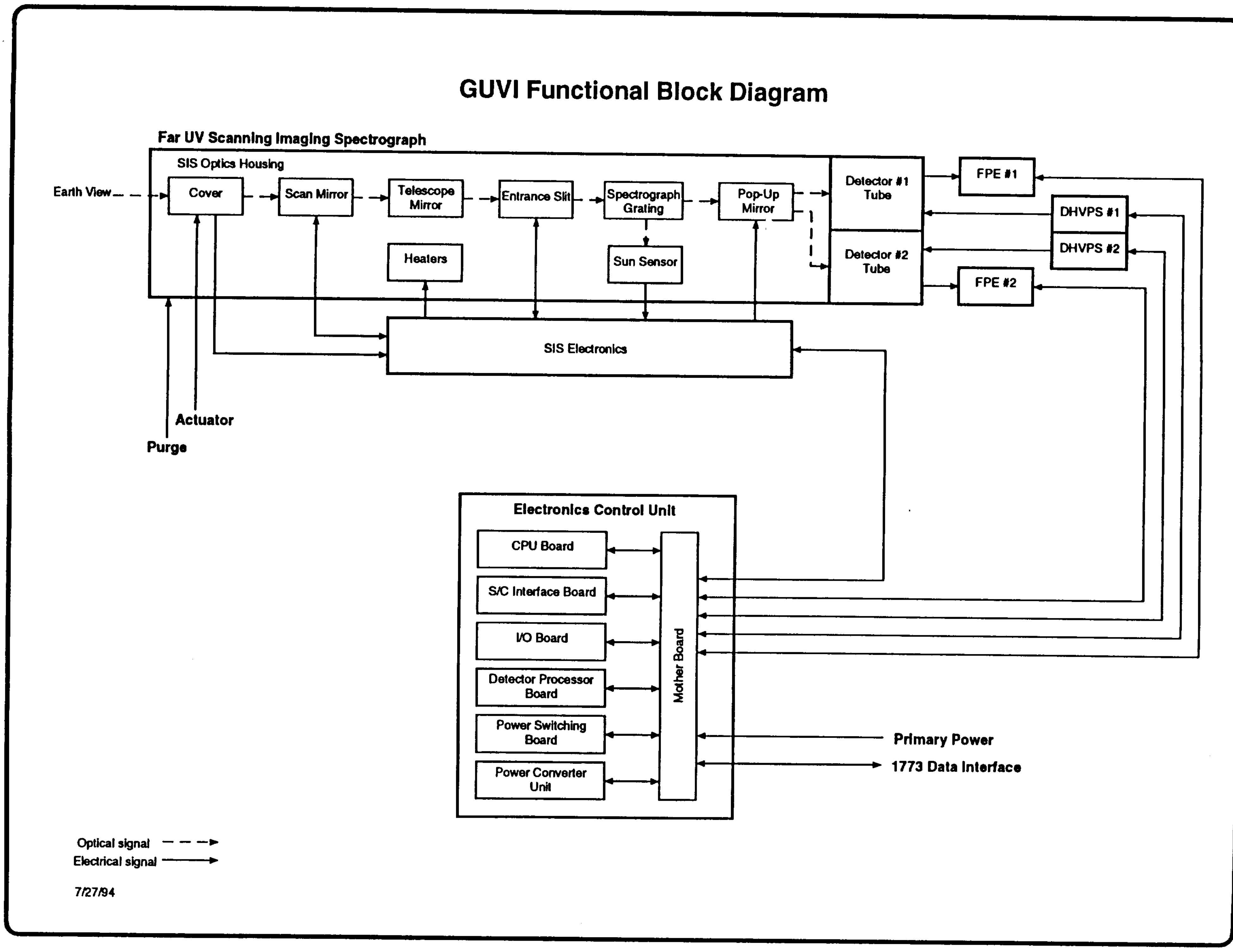
Avoid prolonged exposure of scan mirror to the sun.

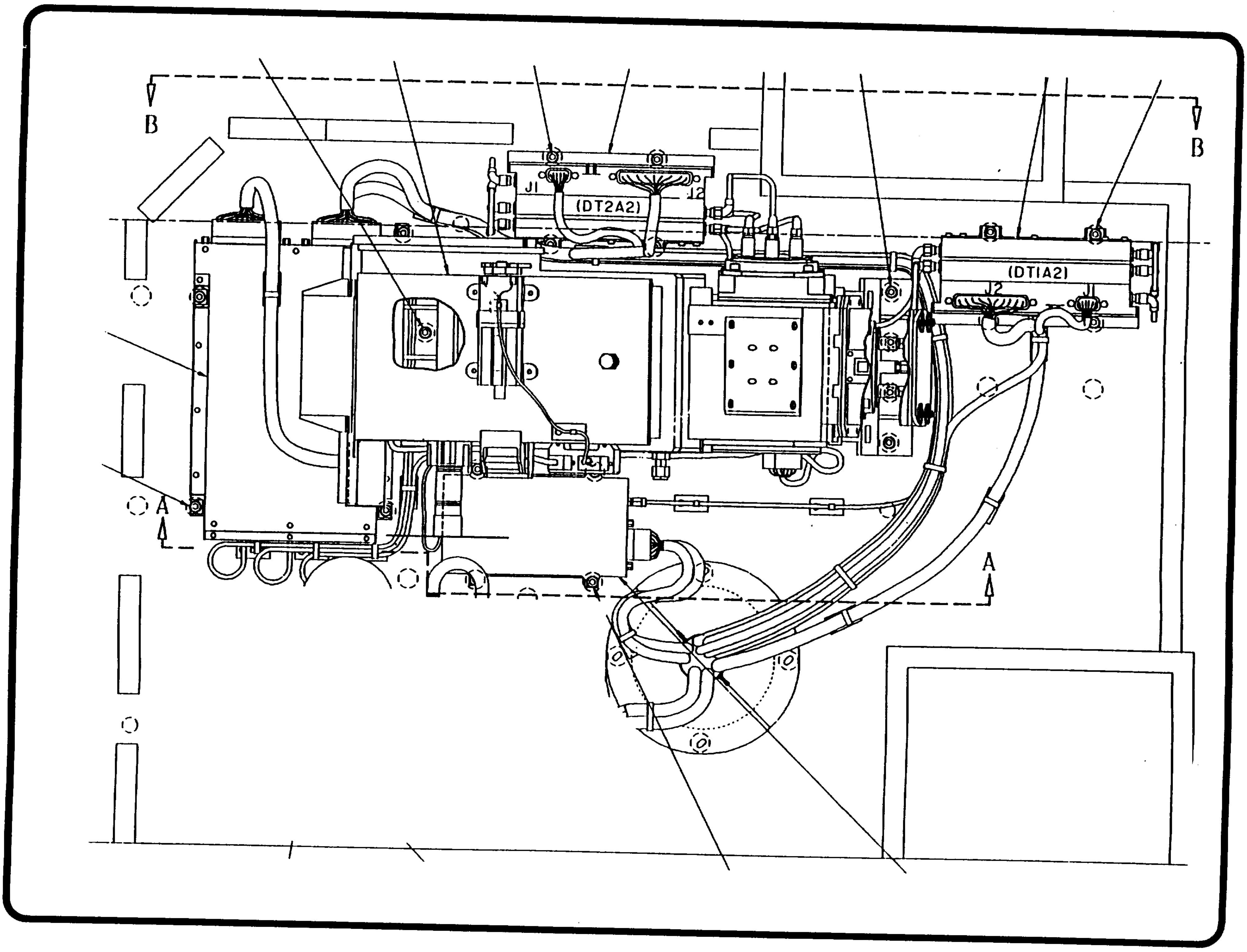
No reclosable cover is needed. (This is a simplification from the original proposal.)

Global Ultraviolet Imager (GUVI)

Technical Description

B. S. Ogorzalek
JHU/APL


GUVI Functional Block Diagram
Far UV Scanning Imaging Spectrograph
SIS Optics Housing
Earth View
Cover
Scan Mirror
Telescope Mirror
Entrance Slit
Spectrograph Grating
Pop-Up Mirror
Detector #1 Tube
Detector #2 Tube
FPE #1
FPE #2
DHVPS #1
DHVPS #2
Heaters
Sun Sensor
SIS Electronics
Actuator
Purge
Electronics Control Unit
CPU Board
S/C Interface Board
I/O Board
Detector Processor Board
Power Switching Board
Power Converter Unit
Mother Board
Primary Power
1773 Data Interface
Optical signal
Electrical signal
7/27/94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J1
(DT2A2)
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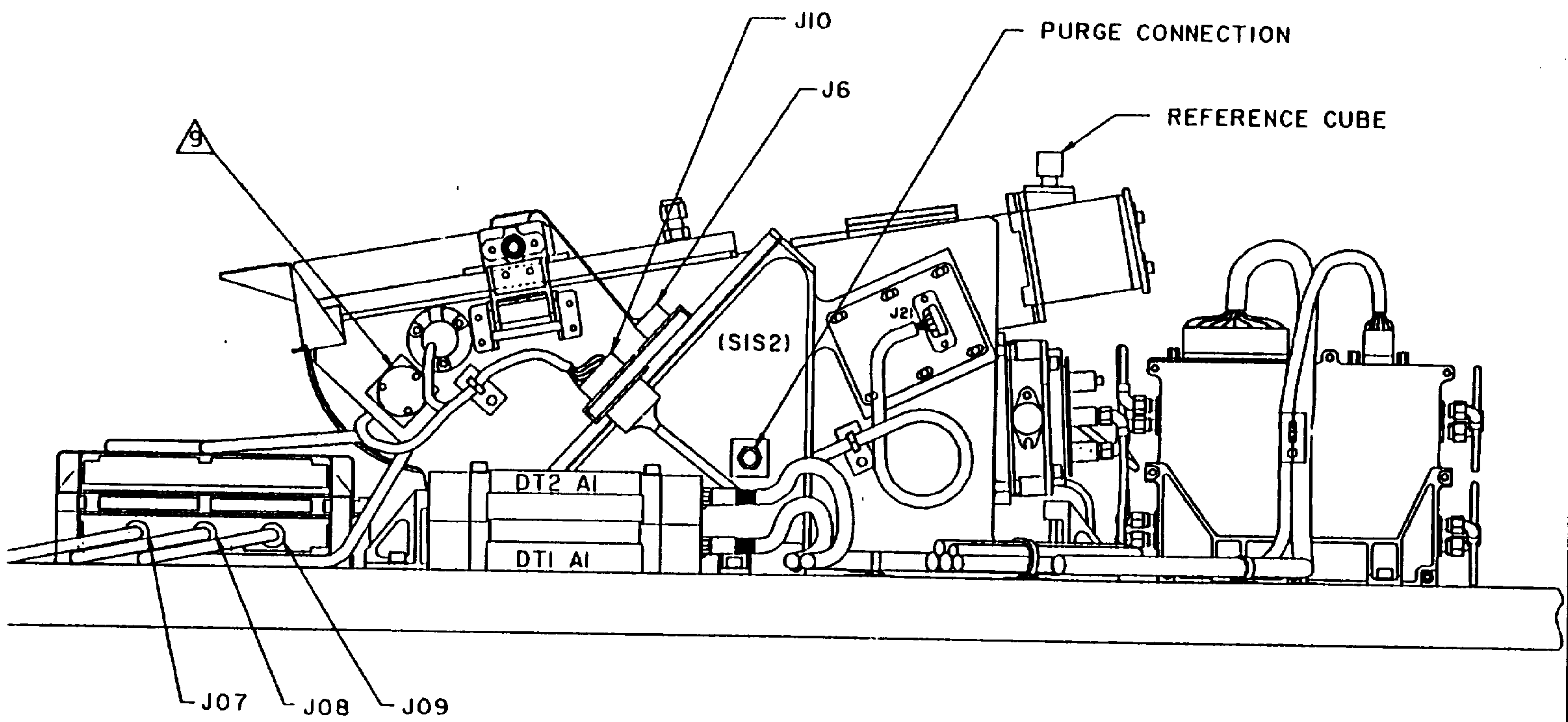
A



VIEW A-A

(MOTOR RADIATOR NOT SHOWN FOR CLARITY)

GUVI SPECIFICATIONS

MASS

Component	Mass (kg)
SIS Housing	6.4
SIS Electronics	1.2
DHVPS	1.0
FPE #1	0.8
FPE #2	0.8
ECU	7.0
Harness	2.0
Total	19.2

10% contingency on SIS Housing
20% contingency on ECU
150 cm harness length

GUVI SPECIFICATIONS

VOLUME

Component	Volume (LxWxH cm)
SIS Housing	48 x 24 x 21 (30 H when cover open)
SIS Electronics	25 x 17 x 6
DHVPS	15 x 10 x 6
FPE #1	15 x 6 x 12
FPE #2	15 x 6 x 12
ECU	38 x 23 x 20
SIS Subsystem Envelope	76 x 36 x 21 (for layout shown earlier)

LAYOUT RESTRICTIONS

SIS Electronics	within 15 cm of SIS scan motor
DHVPS	within 30 cm of both tubes
FPE #1	within 10 cm of tube #1
FPE #2	within 10 cm of tube #2
ECU	within 150 cm of SIS subsystem

GUVI SPECIFICATIONS

POWER

	Power (W)
Operating Average	24
Operating Peak	29
Standby	4

No thermal control power included.

TEMPERATURE

	Operating	Survival
SIS	-20°C to +40°C	-29°C to +50°C
ECU	-24°C to +61°C	-29°C to +66°C

GUVI SPECIFICATIONS

ALTITUDE

Operating	400 km to 600 km
Preferred	600 km

DATA RATE

	Rate (kbps)	
Science	7.8	(for 600 km orbit)
Housekeeping	0.1	

DATA FRAME

Image Size	180 cross track x 16 along track pixels	
Colors	5	
Pixel Size	8 bits	
Frame Period	15 sec	(for 600 km orbit)

GUVI SPECIFICATIONS

FIELD OF VIEW

±6 deg along track
+73 deg to -67 deg across track
Nadir Pointing

ALIGNMENT

Placement	1.0 deg
Knowledge	0.3 deg
Jitter	0.4 deg / sec
Stability	1.0 deg / sec

UNCOMPENSATED MOMENTUM

Scan Mirror	0.002 inch-lb-sec
Cover	4.5 inch-lb-sec

GUVI DESIGN

Scanning Imaging Spectrograph (SIS)

Function:	Far UV Spectrograph with Redundant Detectors
Components:	SIS Optics Housing SIS Electronics
Heritage:	SSUSI Instrument on DMSP Spacecraft
Mechanisms:	Scan Motor Entrance Slit (2 vanes) Pop-up Mirror Protective Cover
Acquisition:	Subcontract
Changes:	Thermal Design / Mounting Feet

GUVI DESIGN

Detector Tubes

Function:	Two-dimensional sensors Mount on SIS Optics Housing Two Tubes for Redundancy Wedge-and-Strip Anode Tube 25 mm diameter Cesium Iodide Photocathode
Heritage:	SSUSI Instrument
Acquisition:	Subcontract for Bare Tube APL Build for HV Bias Boards and Tube Housing
Changes:	None Planned

GUVI DESIGN

Detector Focal Plane Electronics (FPE)

Function:	Digitizes Tube Pulse Heights for Event Processing Contains Pre-Amplifiers and A/D Converters Maximum count rate = 200 k counts/sec Two Units for Redundancy
Heritage:	SSUSI Instrument
Acquisition:	APL Build
Changes:	None Planned

GUVI DESIGN

Detector High Voltage Power Supply (DHVPS)

Function:	Provides High Voltage Power for Detector Tube Adjustable Single High Voltage Output Two Units for Redundancy
Heritage:	SSUSI Instrument
Acquisition:	Subcontract
Changes:	None Planned

GUVI DESIGN

Electronics Control Unit (ECU)

Function:
- Interface with S/C Data and Command Subsystem
- Condition Primary Power for GUVI Subsystems
- Control Operation of SIS and Detector Subsystems
- Format GUVI Science and Housekeeping Data
- Process Detector Events

Components:
- Mother Board (Backplane)
- Power Converter Unit
- Power Switching Board
- Central Processing Unit (CPU) Board
- S/C Interface Board
- I/O Board
- Detector Processing Unit (DPU) Board

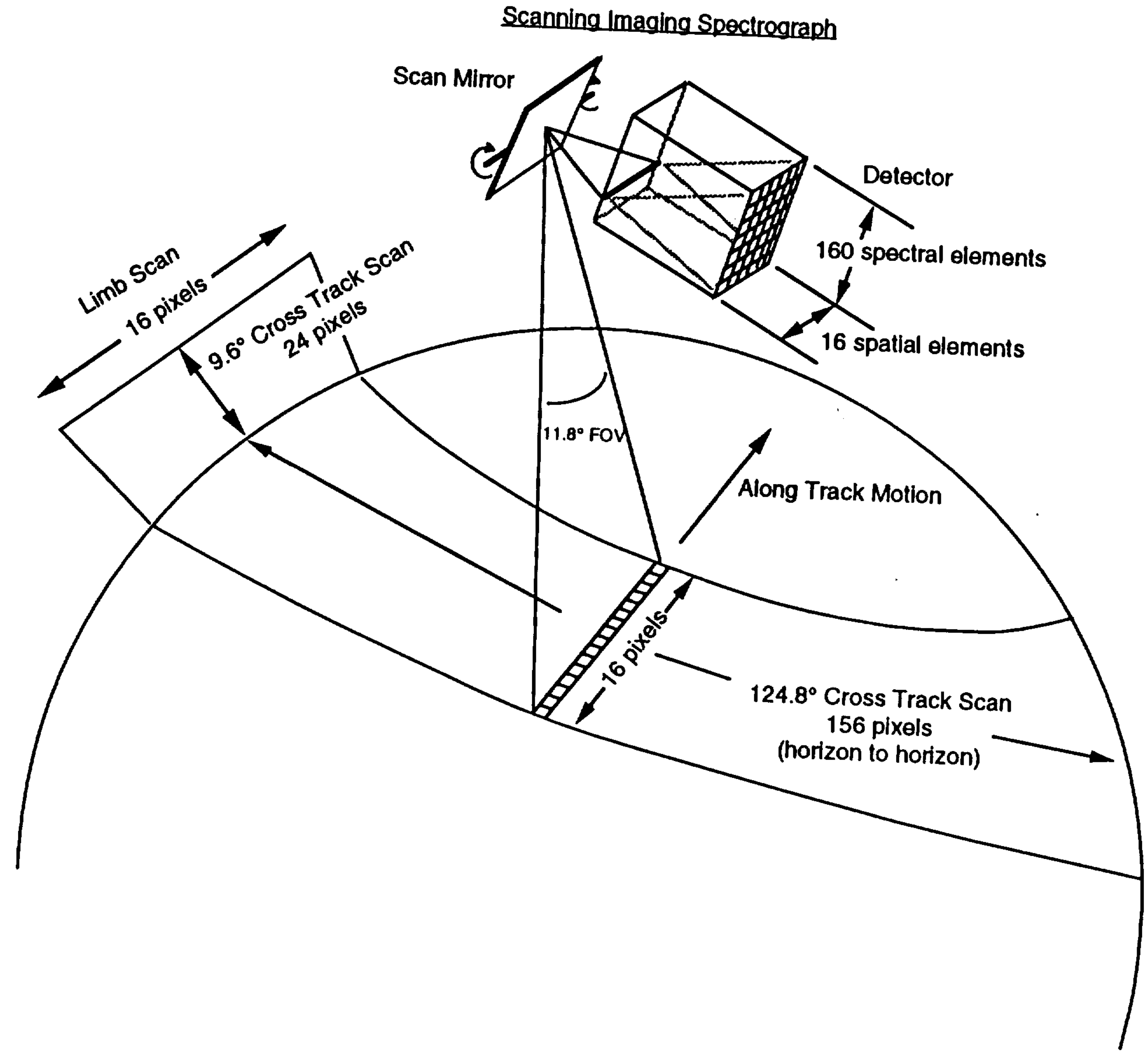
Heritage:
- SSUSI Instrument (Chassis, Mother Board, Power Converter, and DPU Board)
- SAMPEX Instrument (Central Processing Unit)

GUVI DESIGN

Electronics Control Unit (ECU)

Acquisition:	APL Build:	Chassis
		Power Switching Board
		DPU Board
	Aerospace Build:	CPU Board
		S/C Interface Board
		I/O Board
	Subcontract:	Mother Board
		Power Converter Unit
Changes:	Chassis	For 1773 Interface
	Mother Board	New Design
	Power Converter	Change Secondary Voltages
	PSwitch Board	New Design
	CPU Board	New Design
	S/C Int Board	New Design
	I/O Board	New Design
	DPU Board	None

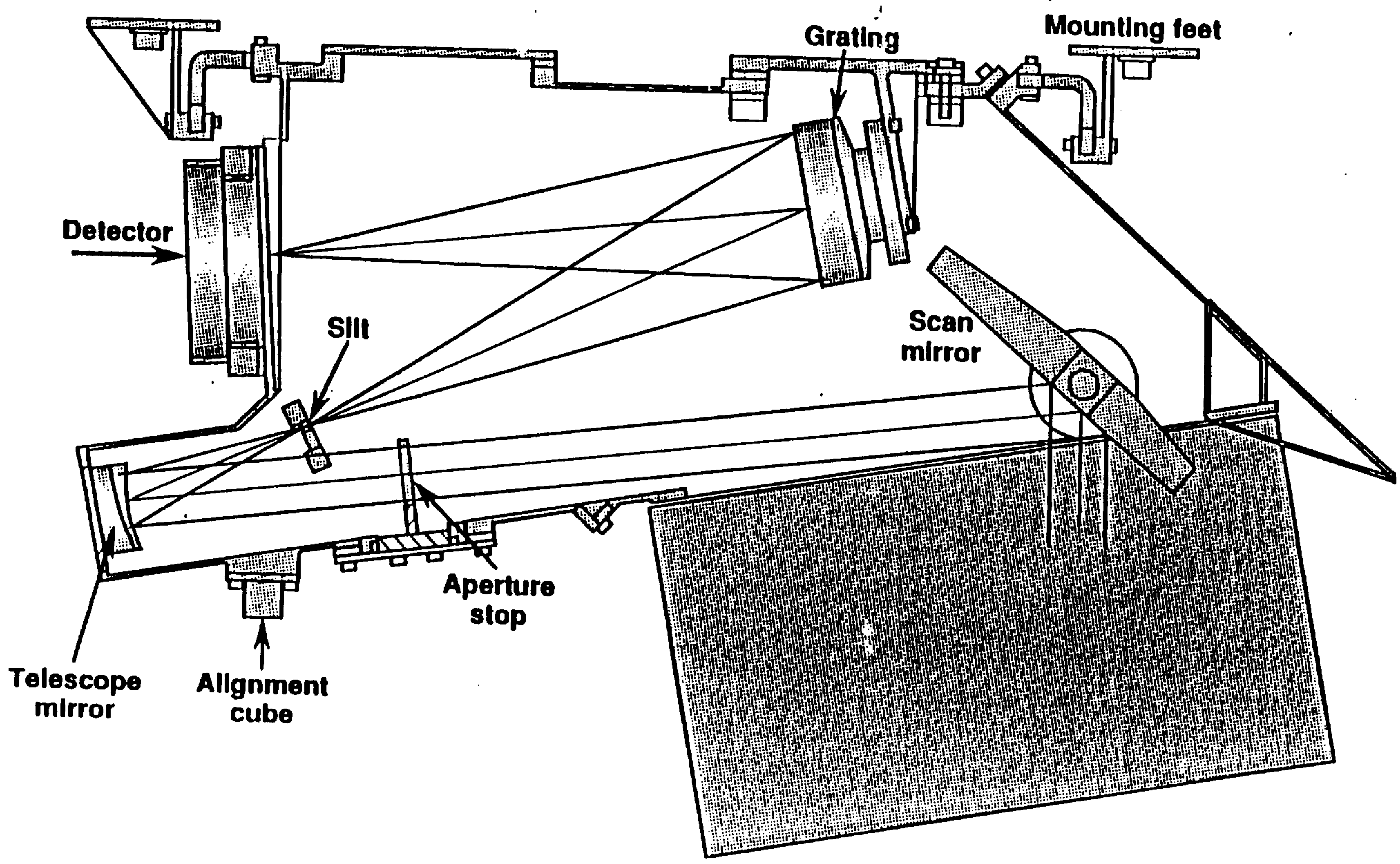
GUVI Imaging Mode

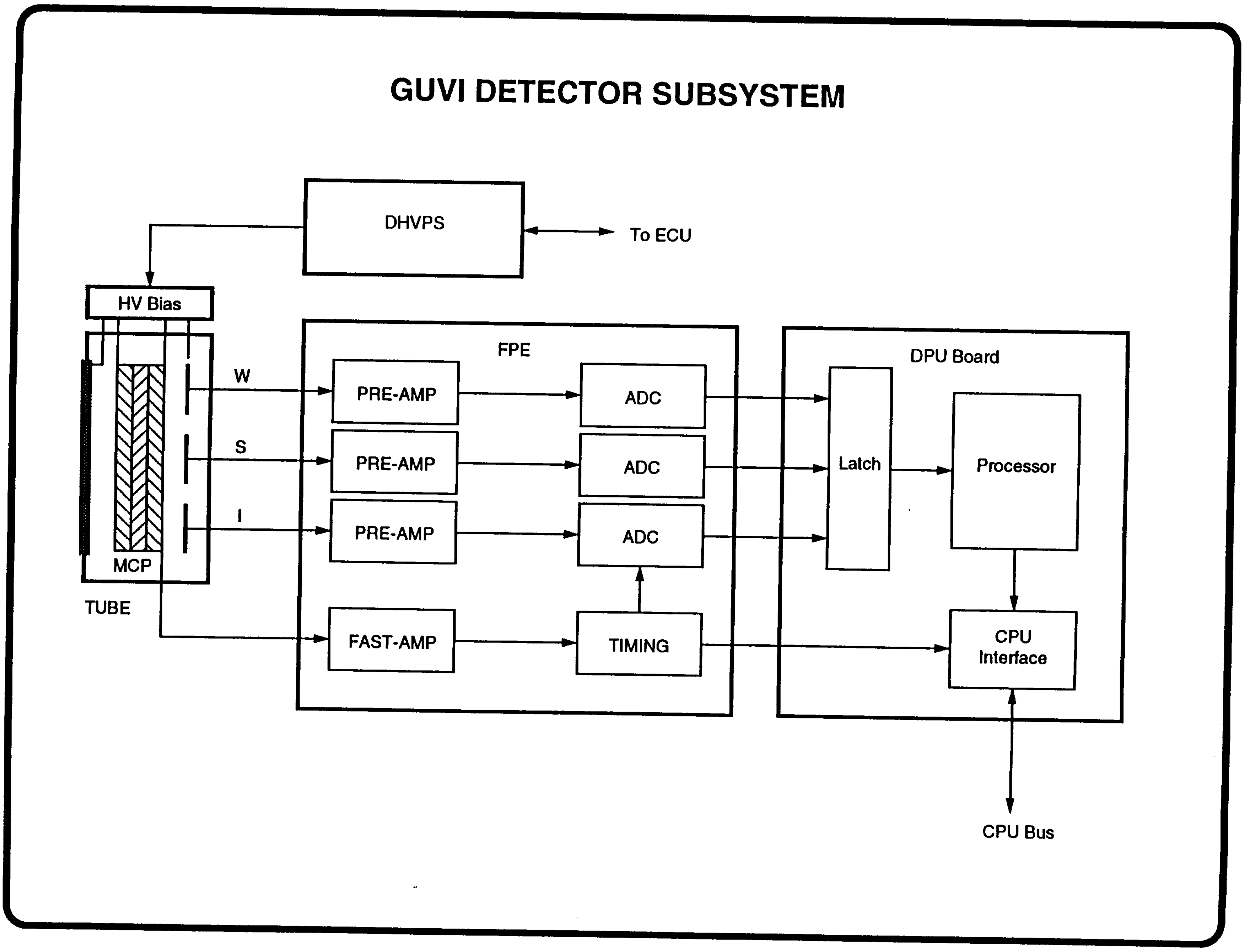


GUVI OPTICAL SPECIFICATIONS

Instantaneous Field of View	cross track	along track	
narrow slit	0.18 deg	11.84 deg	
nominal slit	0.30 deg	11.84 deg	
wide slit	0.74 deg	11.84 deg	
Pixel Field of View	cross track	along track	
narrow slit	0.18 deg	0.74 deg	
nominal slit	0.30 deg	0.74 deg	
wide slit	0.74 deg	0.74 deg	
Scanned Field of View	cross track	along track	step resolution
Limb	9.6 deg	11.84 deg	0.4 deg
Earth	124.8 deg	11.84 deg	0.8 deg
Spatial Resolution at Nadir	cross track	along track	
600 km orbit	7 km	7 km	
Spectral Range	115 nm to 180 nm		
Spectral Resolution			
narrow slit	1.3 nm		
nominal slit	2.0 nm		
wide slit	4.2 nm		

SIS SIMPLFIED SCHEMATIC




GUVI DETECTOR SUBSYSTEM
DHVPS
To ECU
HV Bias
FPE
DPU Board
W
S
I
PRE-AMP
PRE-AMP
PRE-AMP
ADC
ADC
ADC
Latch
Processor
MCP
TUBE
FAST-AMP
TIMING
CPU
Interface
CPU Bus

GUVI FLIGHT SOFTWARE REQUIREMENTS

Detector Processor Unit (DPU)

Processor:	Harris RTX 2000
Language:	Forth
Module 1:	Monitor
Function:	Bootstrap Loader and Debug Monitor
Memory:	Stored in PROM on DPU Board
Size:	4k bytes
Module 2:	Event Processing
Function:	Compute X-Y Position from FPE Pulse Height Data Accumulate Focal Plane Image
Memory:	Download from CPU Board EEPROM Execute from DPU Board RAM
Size:	8k bytes
Heritage:	SSUSI Instrument
Changes:	Modification of focal plane parameters for GUVI modes

GUVI PRODUCT ASSURANCE

GUVI to use APL Product Assurance Implementation Plan

Aerospace and Subcontractors to follow APL PAIP

No GUVI Engineering Model

Configuration Requirements

	Flight	GSE
Drawing level	2A	1
Hardware configuration	B	C
Preferred Parts Grade	2	4

GUVI ENVIRONMENTAL TESTING

Major subcontract items to be tested by vendor before delivery to APL.

SIS: vibration and thermal vacuum tests

Power converter: vibration and thermal vacuum tests

All electronics packages to be thermal cycle tested in-air before integration.

Instrument integration performed at APL.

Pre-environmental optical calibration performed at APL.

Vibration and thermal vacuum testing performed at APL after initial calibration.

Test levels TBD

Final optical calibration performed at APL after environmental tests.

No EMI testing unless major changes made to Power Converter.

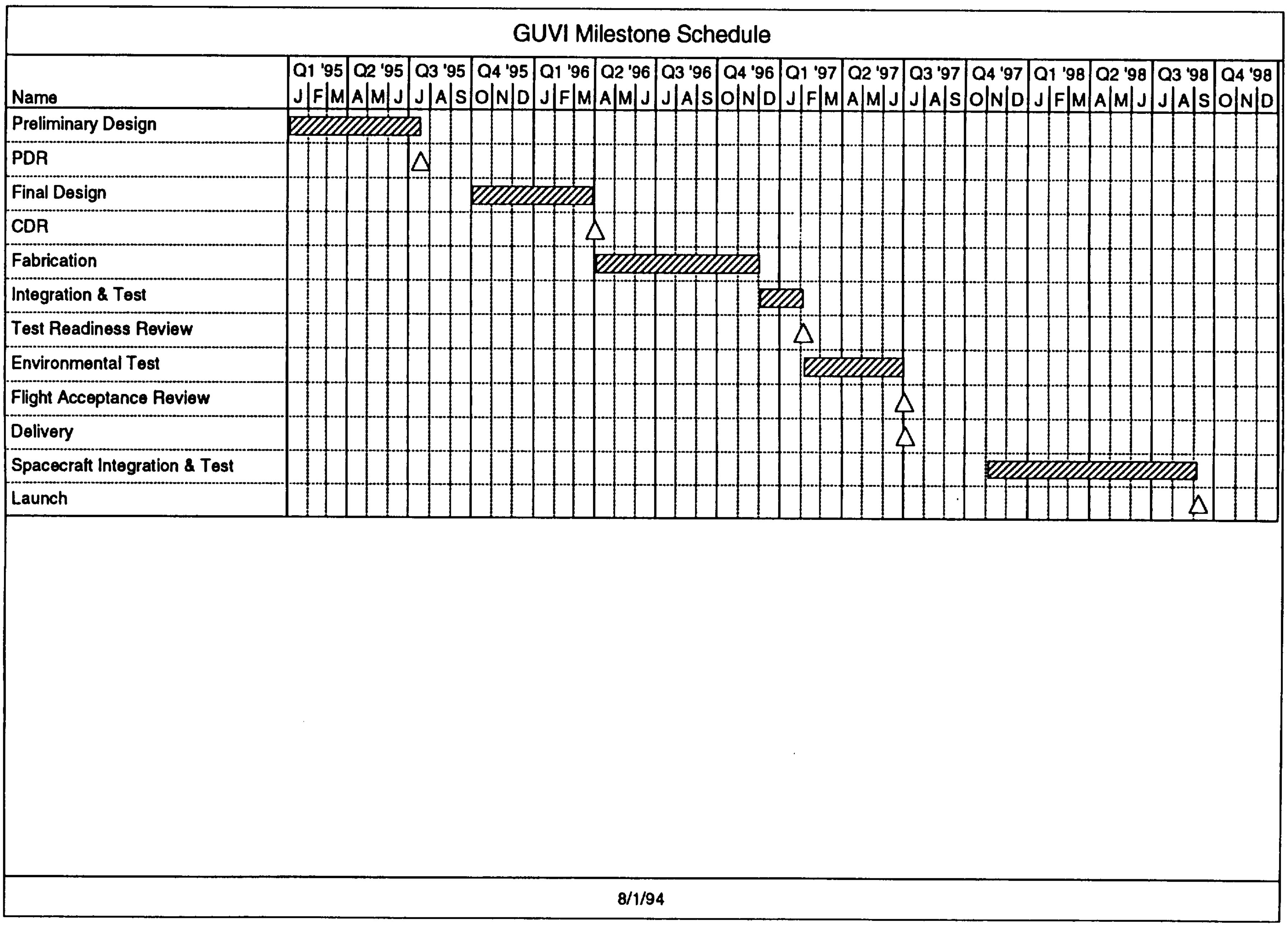
SSUSI EMI test results available.

Contamination control plan to be implemented to ensure instrument cleanliness.

GUVI SCHEDULE & COST

B. S. Ogorzalek

JHU/APL


GUVI Milestone Schedule
Name
Q1 '95 Q2 '95 Q3 '95 Q4 '95 Q1 '96 Q2 '96 Q3 '96 Q4 '96 Q1 '97 Q2 '97 Q3 '97 Q4 '97 Q1 '98 Q2 '98 Q3 '98 Q4 '98
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Preliminary Design
PDR
Final Design
CDR
Fabrication
Integration & Test
Test Readiness Review
Environmental Test
Flight Acceptance Review
Delivery
Spacecraft Integration & Test
Launch
8/1/94

GUVI TOTAL COST

PHASE C/D

Amounts in K$	1995 Oct-Dec	1996 Jan-Sep	1996 Oct-Dec	1997 Jan-Sep	1997 Oct-Dec	1998 Jan-Sep	Total
GUVI Total Cost	963	2199	1280	1619	237	515	6813

GUVI EXPERIMENT

TIMED

Flight Software (Telemetry Processor)

- Event driven; operations scheduled at 10 msec interval timeout
- Flight software written in C and Assembler (where time cliticality is important)
- Spacecraft command interface provides for code and data upload and program modification
- Test concept:
  - First-level verification is performed with software simulator
  - GSE simulates sensor data output, then verifies expected output at the spacecraft simulator's telemetry link; Similarly GSE simulates spacecraft command output, then verifies expected control changes at sensor simulator
  - Closed loop GSE concept, along with command language allow for test procedures to be written which test all S/W & H/W functions

GUVI EXPERIMENT

TIMED

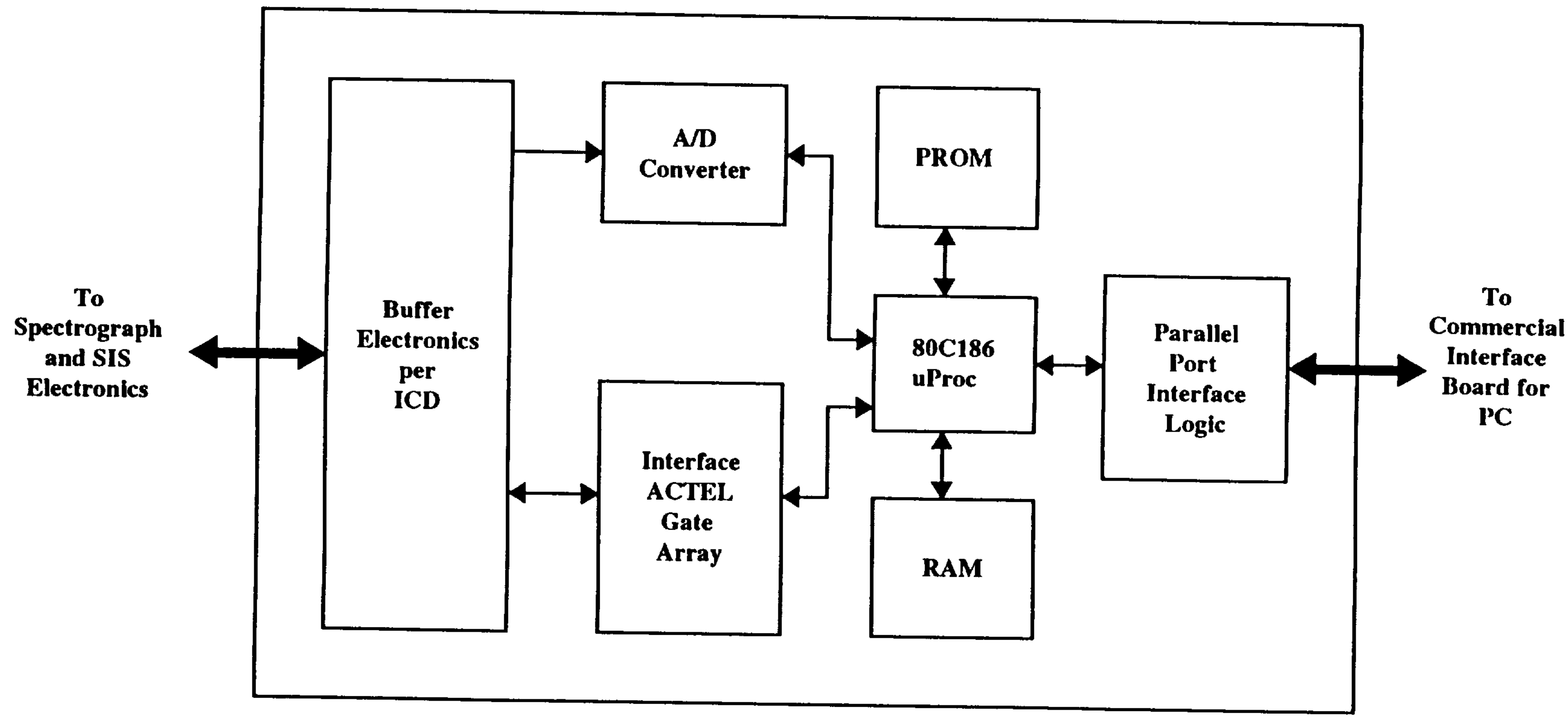
Telemetry Processor Board

- Operations Performed:
  - Coordinate sensor data acquisition
  - Packetize telemetry (science & housekeeping) for delivery to spacecraft
  - Receive and validate spacecraft commands prior to execution
- Processor Board features:
  - Intel 80C186 microprocessor
  - 128Kb SRAM (fault tolerant design)
  - 32Kwords ROM
  - Support for 8 external interrupts, 2 DMA channels
  - Watchdog timer

GUVI EXPERIMENT

TIMED

ECU Interface Simulator



GSE Design

SOFTWARE

- Macintosh platform
- Automated Control Language -- macro driven
- Science and Engineering displays and functions
- Interface to the Calibration Equipment

HARDWARE

- 68000 Microprocessor-based
- Simulate spacecraft interface
  - 1773 Bus or RS422 interface
  - Power interface
- Exercise sensor interface to ECU
  - Test patterns

Ground Support Equipment

Stage 1 -- Verification of Engineering Aerospace boards in ECU

- Simulate Spacecraft Function
- Stimulate the ECU in place of the Detector processor

Stage 2 -- Complete System Testing

- Verify the Science of the Instrument
- Integrate the Sensor
- Support Functional testing, Thermal/Vac, EMC/EMI testing

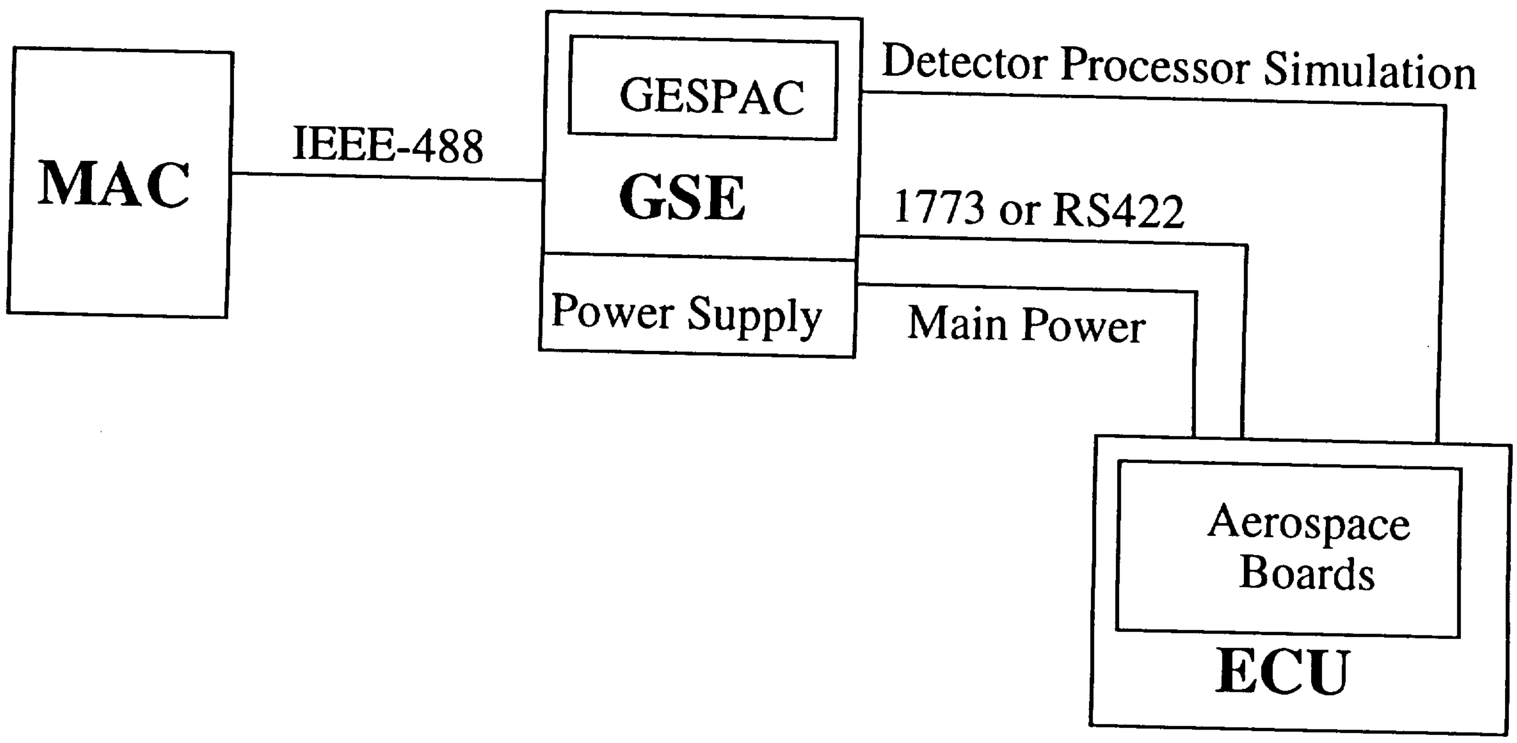
Stage 3 -- Full System Calibration Support

- Calibrate the Instrument
  Control of the Stimuli Equipment through RS-232 to APL PC

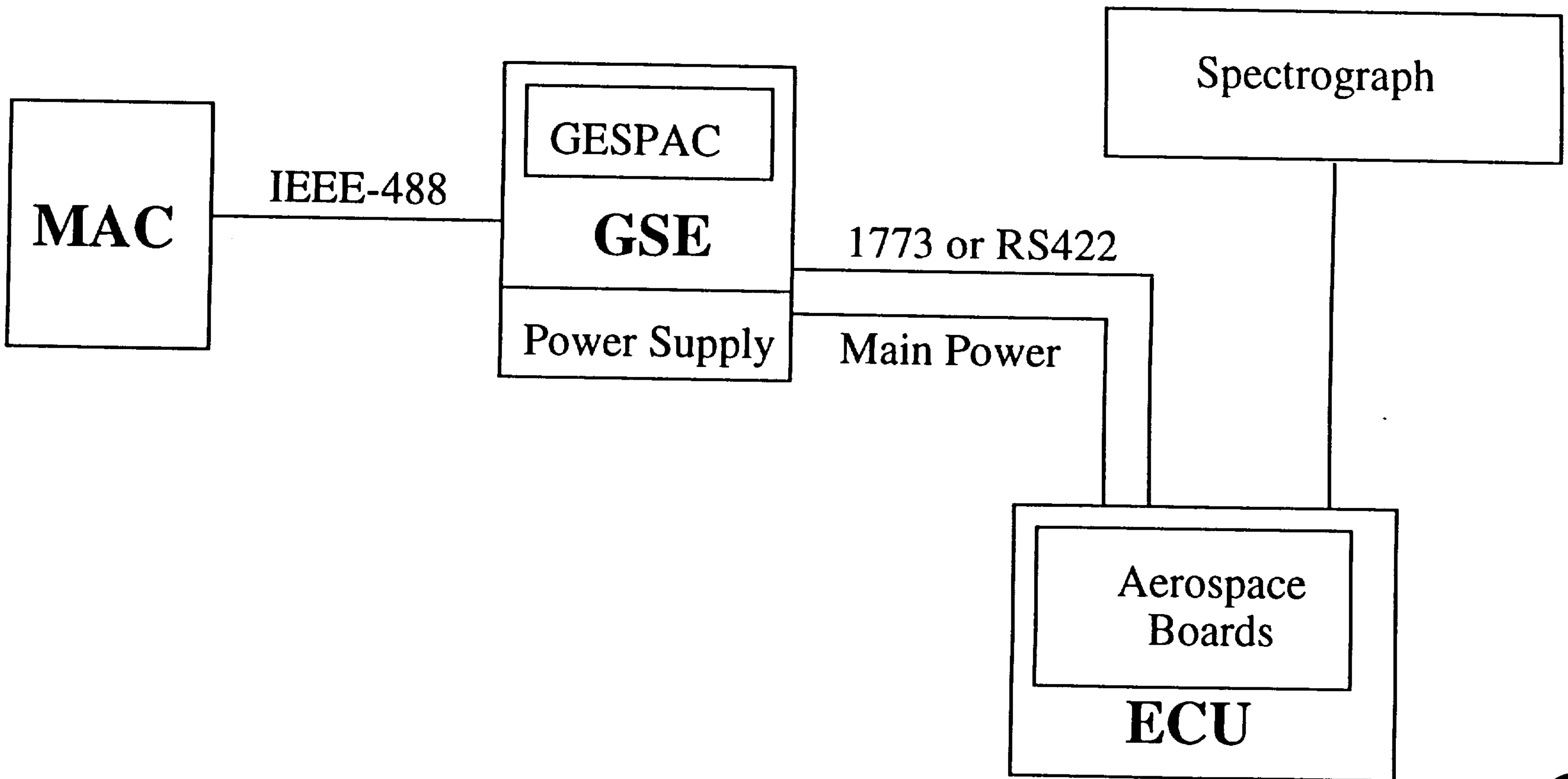
Stage 4 -- Integration and Test Support

- Listen to the Spacecraft Checkout System

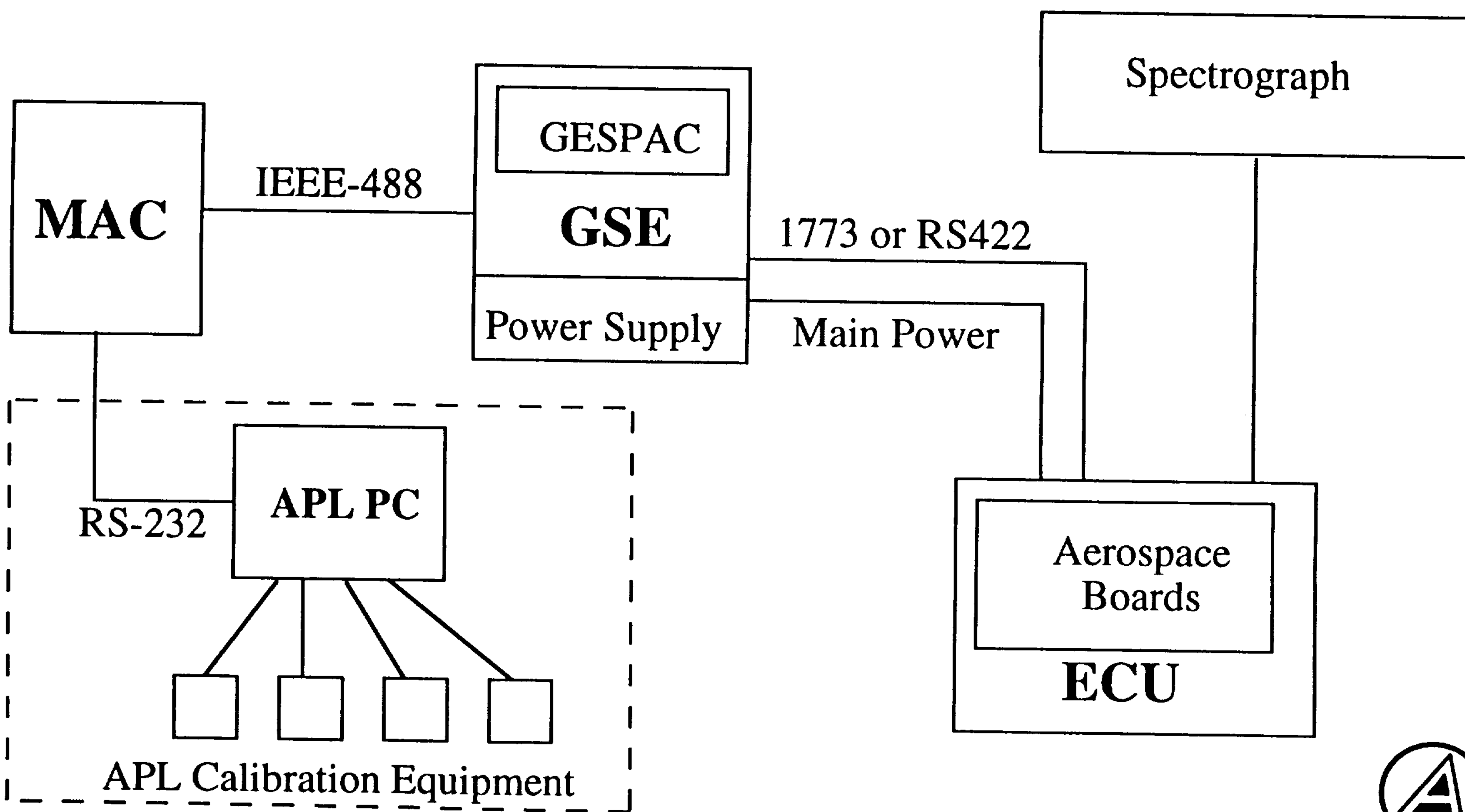
GSE Configuration -- Stage 1



GSE Configuration -- Stage 2

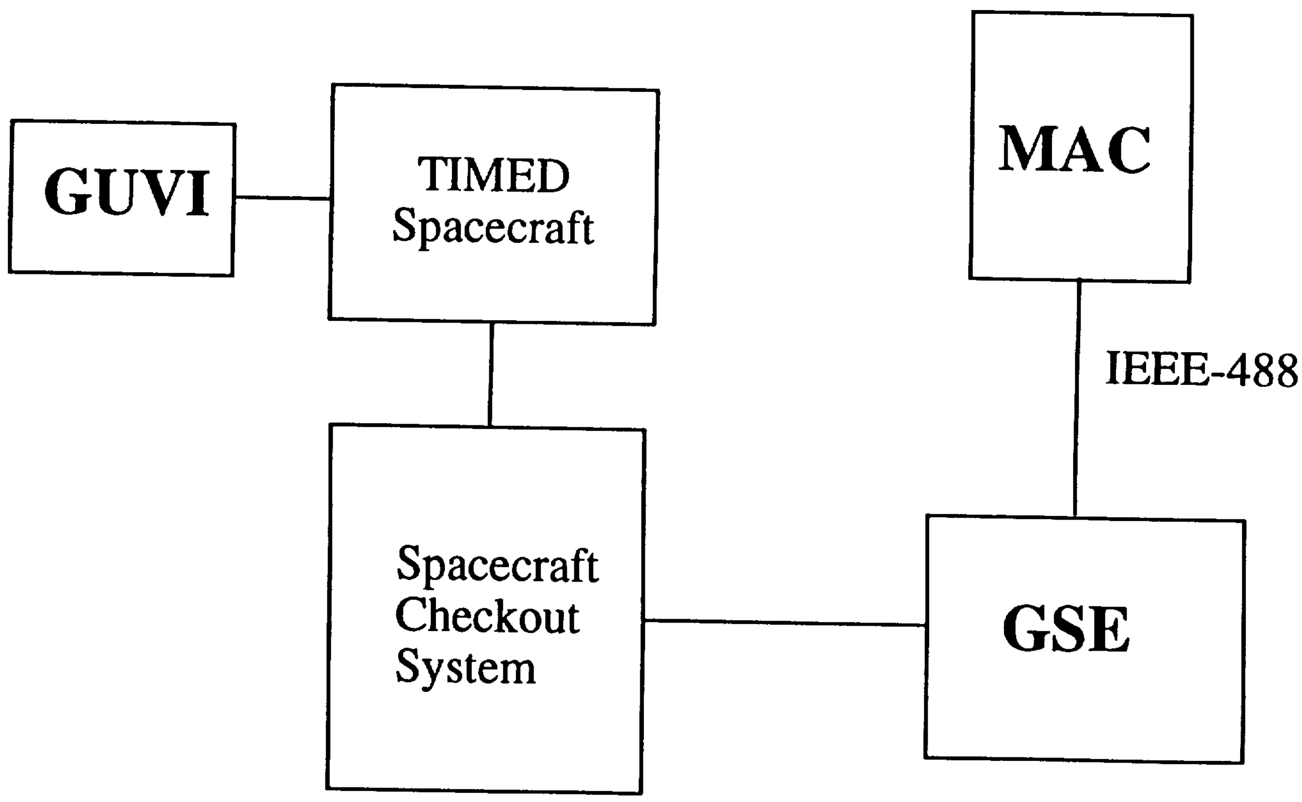


GSE Configuration -- Stage 3



TIMED **GUVI EXPERIMENT** TIMED

GSE Configuration -- Stage 4



Science Parameter Extraction

Dr. Larry J. Paxton
Space Department
S1G-Geospace Remote Sensing
The Johns Hopkins University
Applied Physics Laboratory

Cost Saving Strategy

We can significantly reduce the TIMED project cost for GUVI and still have data analysis tools in place before launch by using code developed under DMSP programs.

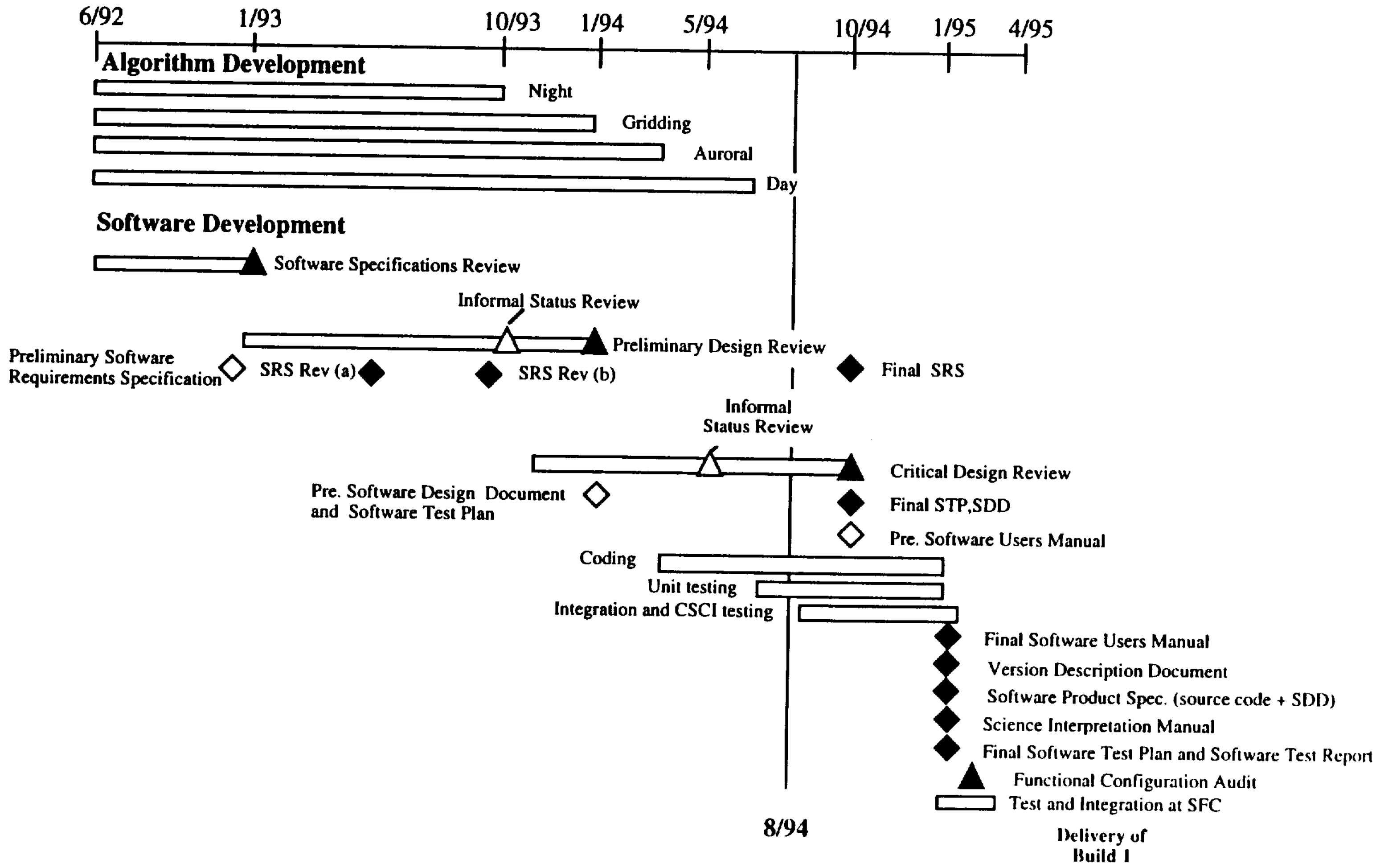
- most of the code is based on the SSUSI algorithms and display software
- some additional modules and capabilities are also being produced for GUVI by a co-I for the SSULI program Dr. Bob Meier).

Before SSUSI launch, SSUSI algorithms will be validated with MSX data as will the relevant SSULI algorithms. SSULI/SSUSI may see additional validation with RAIDS data.

MSX has a mission lifetime goal of five years and so may well be in operation when TIMED flies.

The first SSUSI and SSULI may fly as early as 1997 or as late as 1999 and four more launches are scheduled after that on about three year centers.

SSUSI GDAS
Development Schedule



SSUSI as a Paradigm

SSUSI Ground Data Analysis Software is currently being built. The final delivery will be in June 1995.

- **contract is for $4M**
- **algorithms are written in Ada**
  - required documentation to MilSpec 2167A
  - language independent descriptions of all algorithms are developed
  - object oriented approach used

The user interface is written in PV Wave.

Data processing is designed such that each orbit will be completely processed in about 20minutes on a shared Dec Alpha.

Changes to Existing Software

Translating SSUSI to GUVI means redefining databases used in algorithms.

The user interface will be robust enough to support the GUVI observing geometry since all modules have been written such that observing displays are independent of observing geometry.

SSULI algorithms deal just with the limb but yield an additional level of robustness to the inversion process by providing an independent approach. SSULI interface is compatible with the SSUSI interface.

Interactive Data Analysis and Display of SSUSI Data

Current effort at APL to support SSUSI GDAS:

L.J. Paxton, G. Crowley, M.M. Hopkins, R. Weed, G. Bodoh, T. Spisz, and L. Suther

and

D.J. Strickland, J.S. Evans, and K.C. Wright

Computational Physics, Inc.

night and auroral algorithms have been supplied by Dr. Dave Anderson (PL/GD), Dr. Rob Daniel (CPI), and Dr. Matthew Fox (BU)

Design Philosophy of the User Interface

The main display is the initial "start-up" configuration

- data are referred to a global projection
- the user can customize display settings
- pull-down menus call other displays and provide access to other functions and data sets
  - file, display, preferences, overlays, utilities, help

Universal features include:

- observer viewing geometry and location
- access to a variety of overlays
- widgets interface
- hardcopy capability

Flexibility is achieved

- by providing hooks for display of other data sets either as overlays or in separate windows
- thru integration of the routines and displays into a common architecture

Approach

The “algorithms” (code used to convert from sensor data numbers to sensor data products) are written first in a language independent description.

- programmers work closely with a small team of scientists

The algorithms are then implemented in an object oriented approach.

The GUI is implemented using IDL/PV Wave.

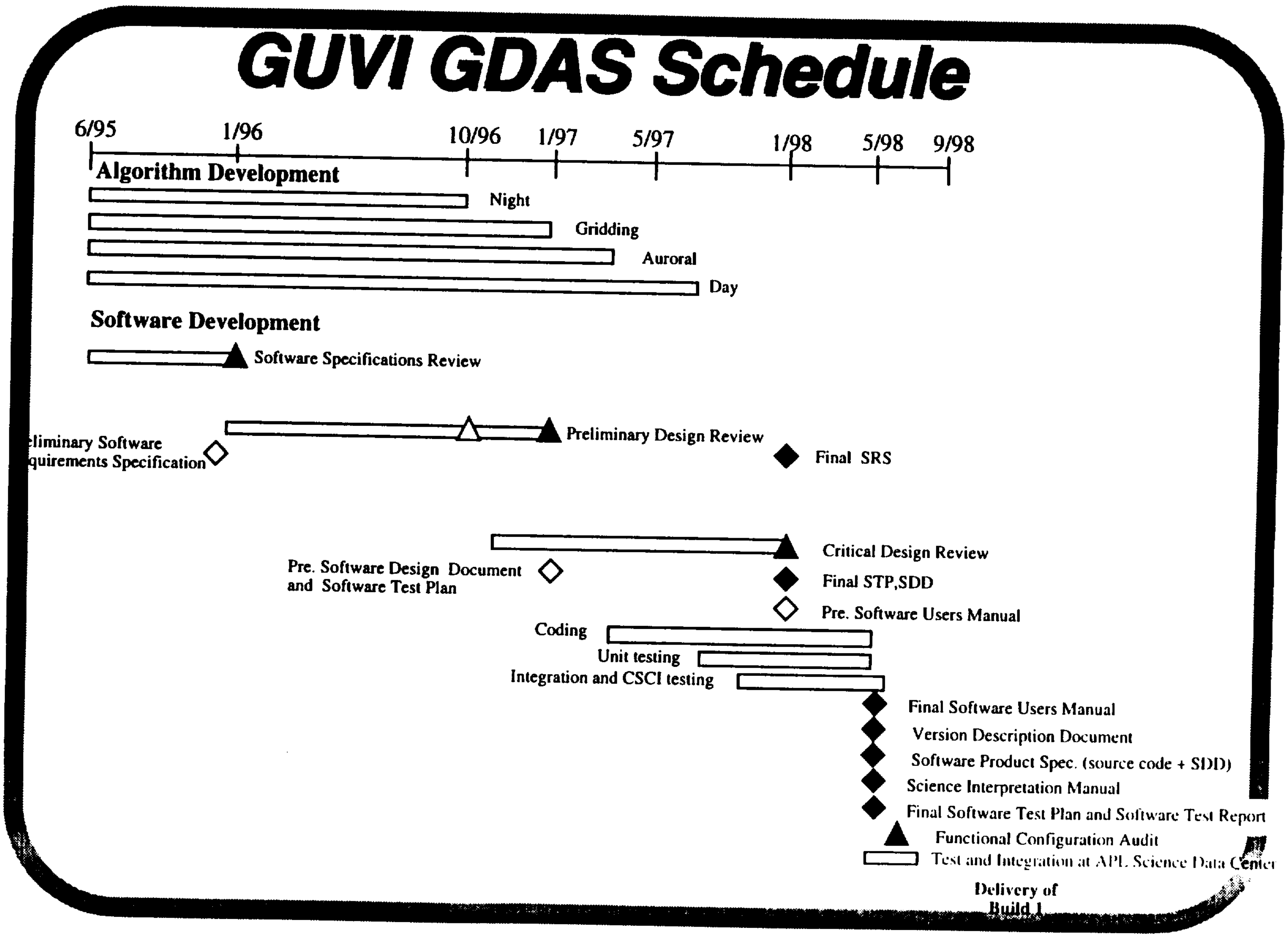
Possibilities

Recent theoretical calculations by Dr. Gary Thomas (UC-Boulder) and Dr. Randy Gladstone (SwRI) have indicated that Polar Mesospheric Clouds could possibly be observed by GUVI.

GUVI would then be the first experiment to image PMC from space and could map their occurence in time and space.

Exisiting SSUSI displays already display H Lyman alpha data

- a new module to determine the geocornal signal and subtract it would be required
- level of effort is small (about 3wm including testing and documentation)


GUVI GDAS Schedule
6/95
1/96
10/96
1/97
5/97
1/98
5/98
9/98
Algorithm Development
Night
Gridding
Auroral
Day
Software Development
Software Specifications Review
liminary Software
quirements Specification
Preliminary Design Review
Final SRS
Critical Design Review
Pre. Software Design Document
and Software Test Plan
Final STP,SDD
Pre. Software Users Manual
Coding
Unit testing
Integration and CSCI testing
Final Software Users Manual
Version Description Document
Software Product Spec. (source code + SDD)
Science Interpretation Manual
Final Software Test Plan and Software Test Report
Functional Configuration Audit
Test and Integration at APL Science Data Center
Delivery of
Build 1

INSTRUMENT DPU

TIMED

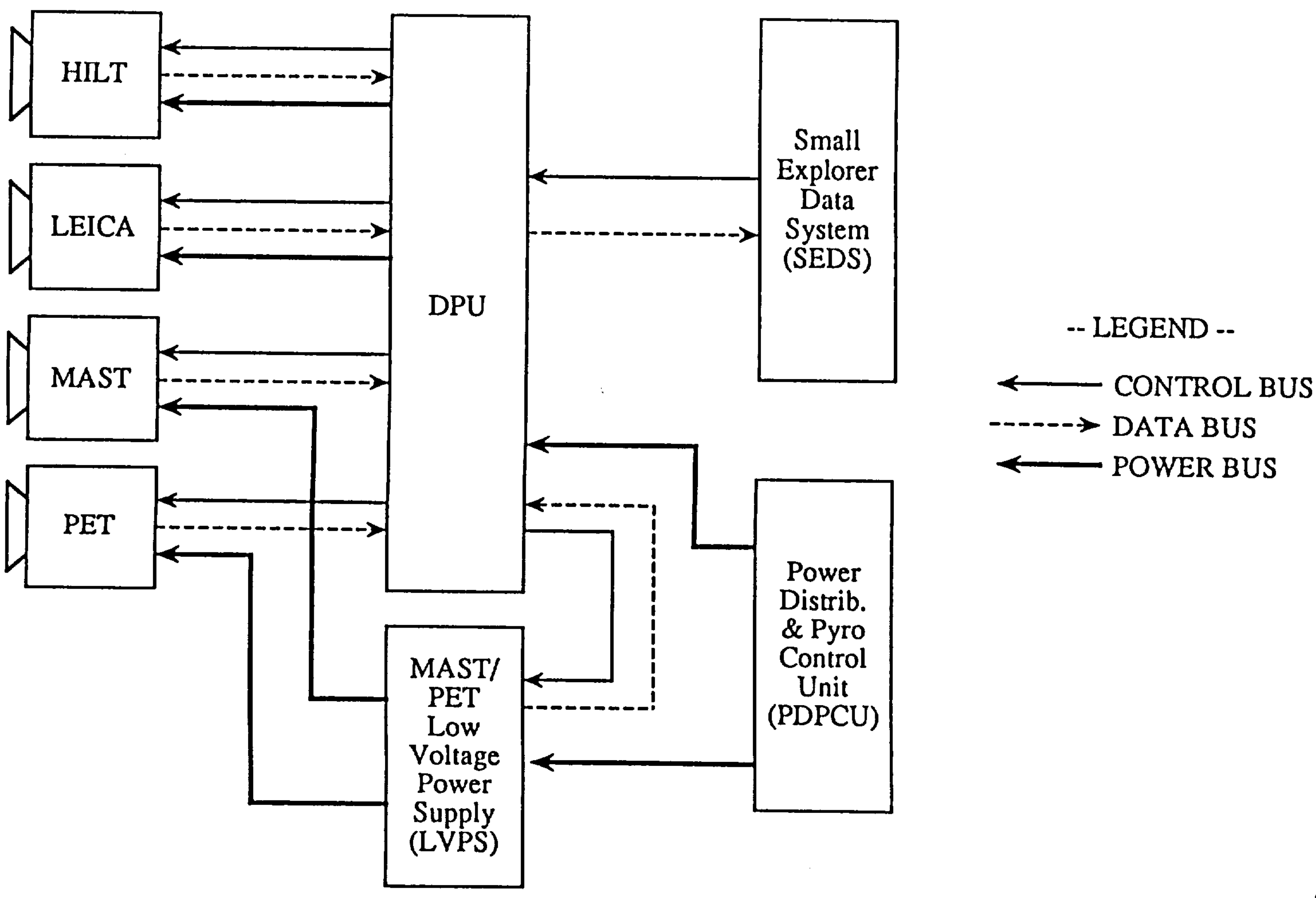
Heritage for Single DPU Concept

- Solar Anomalous, Magnetospheric Particle Explorer (SAMPEX), NASA's first of the revived small explorer program launched July 3, 1992
- Four sensor payload; DPU perform normal data acquisition, compression, and telemetry packet formation; spacecraft command reception/verification and execution (sensor control), and provides other intimate support for sensors (high voltage safing, detector protection, time distribution)
- DPU provides recorder quota system to optimize data storage
- SAMPEX mission concept: 18 month development (contract award to launch); 3 year target mission

INSTRUMENT DPU

TIMED

SAMPEX Block Diagram



INSTRUMENT DPU

TIMED

SAMPEX Organizations

- University of Maryland (P.I. Org): LEICA sensor
- Caltech: MAST and PET sensors
- Max Planck Institut fur Extraterrestrisch Physik (Garching, Germany): HILT sensor
- Goddard Space Flight Center: Small Explorer Data System
- Aerospace Corporation: Common DPU System

INSTRUMENT DPU

TIMED

Results for Common DPU on SAMPEX

- Engineering model DPU was taken to U of MD (LEICA), Caltech (MAST & PET), MPE (HILT), and Goddard (S/C) interface verification. Upon completion, E/M DPU was delivered to Goddard for use in S/C test lab

- Flight model DPU was delivered on schedule

- Aerospace development cost total (DPU and GSE) at launch plus 30 days underran original contract amount by 5% (Phase B/C/D budget was \$1212K; expenditures were \$1148K)

- Flight DPU system has operated fine since launch + 16 hrs (approximately 25 months) in 400 km circular orbit, 93° inclination

INSTRUMENT DPU

TIMED

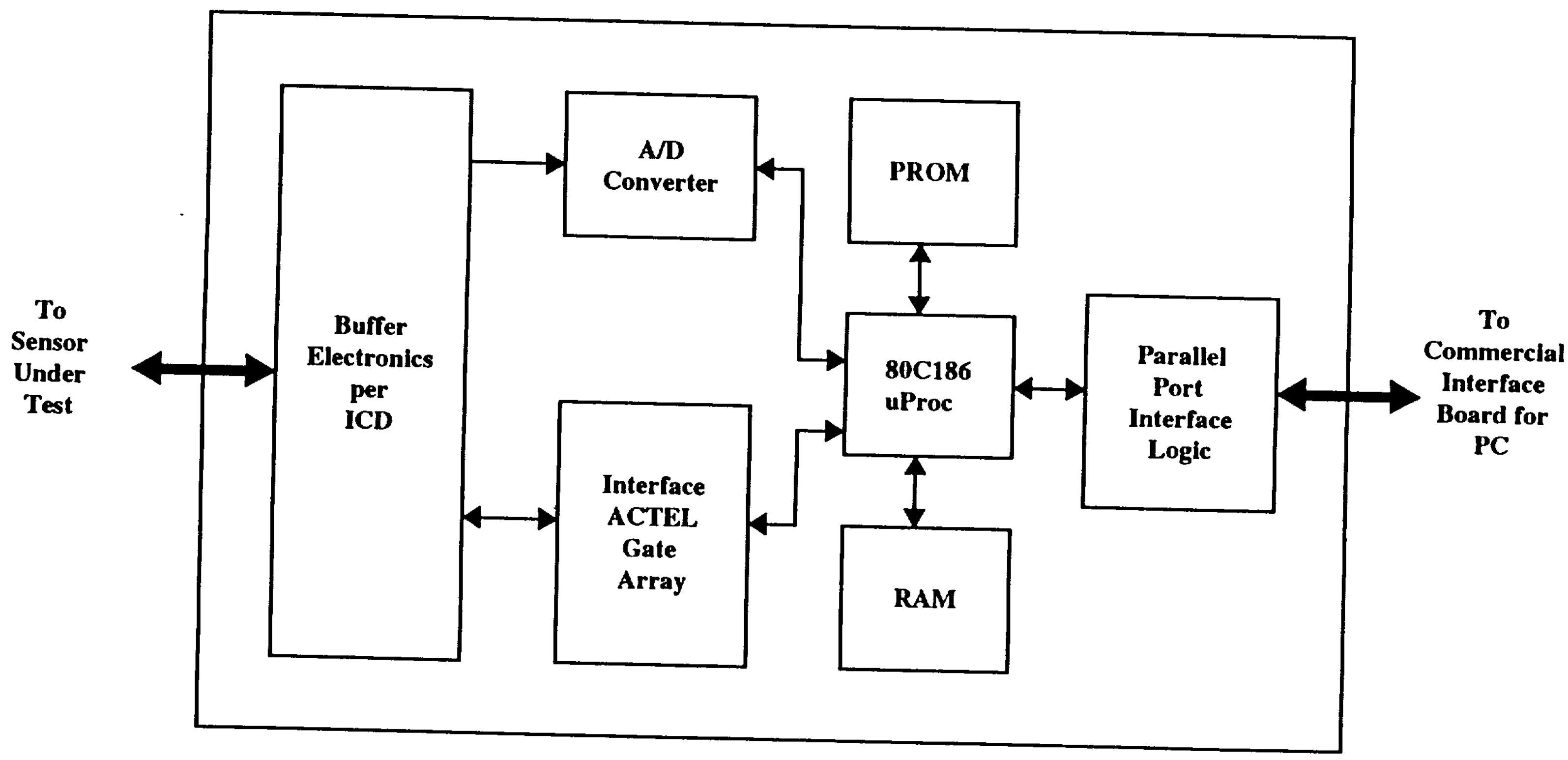
Items Contributing to SAMPEX Success

- ICDs signed off early in program
- Engineering model DPU system taken to each sensor site flushed out interface problems before flight hardware was built. Sensor simulators were also validated in the process
- GSE's sensor simulators helped to uncover software bugs during extensive system testing of DPU
- One item missing from the test equipment was a DPU simulator for each of the sensor's use

INSTRUMENT DPU

TIMED

DPU Interface Simulator



INSTRUMENT DPU

TIMED

Enhancing Reliability in the Common DPU

Provide redundancy in the following areas:

- **Microprocessor electronics (through redundant board)**
- **Spacecraft interfaces**
- **Low voltage power supplies (through redundant board)**

Parts Program:

- **Minimum reliability grade MIL-883; upscreen all parts to comply with Grade 2 parts program**
  - **Excluding passive components, board set consists of 12 items; 4 are UTMC/Harris Class S, 1 is fab'ed to MIL-38510, and 7 are 883B**
- **Some diodes and hand-wound inductors will require rescreening**

INSTRUMENT DPU

TIMED

Assumptions for Costing Common DPU

- Two trips planned to each sensor site to finalize sensor/DPU Interface Control Document (ICD) to include not only signal interface characteristics, but also to clearly define functional requirements

- Simulator to be provided by Aerospace for both the sensor side and the DPU side of the interface. Sensor simulator to be incorporated into the DPU GSE

- In phase C/D, two trips planned to perform the following items:
  - verify the sensor/DPU interface with E/M hardware
  - verify/deliver DPU simulator to sensor developer
  - verify GSE's simulator of sensor interface for DPU development support

- In cost estimates, labor is inflated by 4%/year; materials are inflated by 3%/year

INSTRUMENT DPU

TIMED

Common DPU Pricing vs. GUVI-only Pricing (Aerospace only)

	FY95 (Phase B)	FY96 (Phase C/D)	FY97 (Phase C/D)	FY98 (S/C I/T)	Total
GUVI-only	$208K	$664K	$150K	$85K	$1107K
6 sensors	$301K	$1315K	$538K	$169K	$2323K
increase	$93K	$651K	$388K	$84K	$1216K

GUVI Calibration and Characterization

Dr. Larry J. Paxton
Johns Hopkins University
Applied Physics Laboratory
Laurel, MD 20723

(301) 953-6871
(301) 953-6670 fax

Calibration Matrix

Calibration Test	Bench	Prelim	Pre-env	Post-env
SIS Detector				
Noise Level	X			
Flat Fielding	X			
Output vs Input Count Rate	X			
Pulse Height Distribution	X			
Intrascene Dynamic Range	X			
Interscene Dynamic Range	X			
SIS				
Sensitivity vs Wavelength		X	X	X
Intrascene Dynamic Range		X		
Field of View		X	X	X
Spectral Resolution		X	X	X
Wavelength Scale		X	X	X
Off-axis Rejection		X	X	X
Out of Band Response		X		
Illumination Sensor Threshold		X		

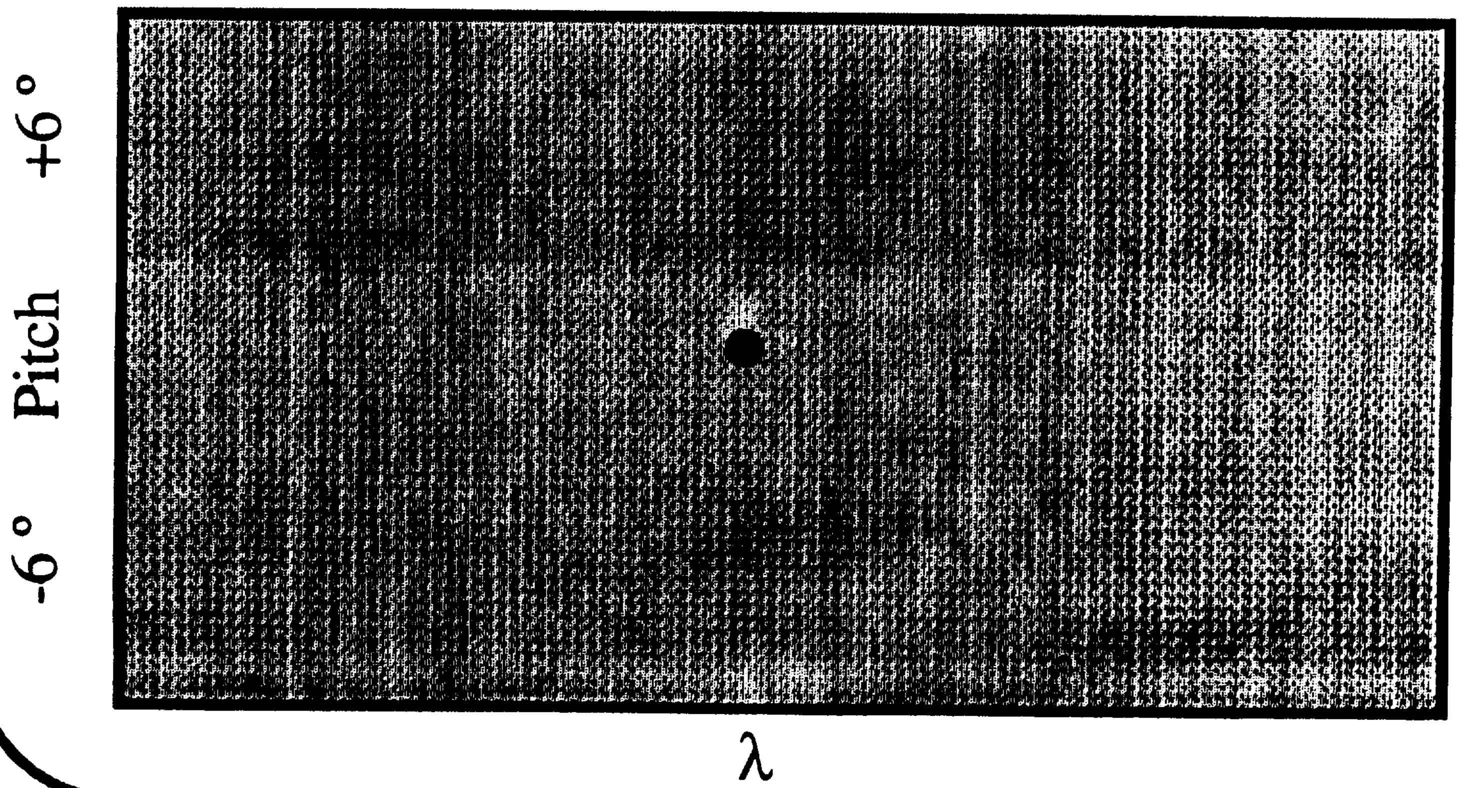
Calibration Goals for SIS

- Understand the instrument.
- Be able to convert measured counts/pixel on-orbit into accurate radiances from a known emission volume.
- Be able to understand on-orbit stellar calibrations.

Point Source Calibration

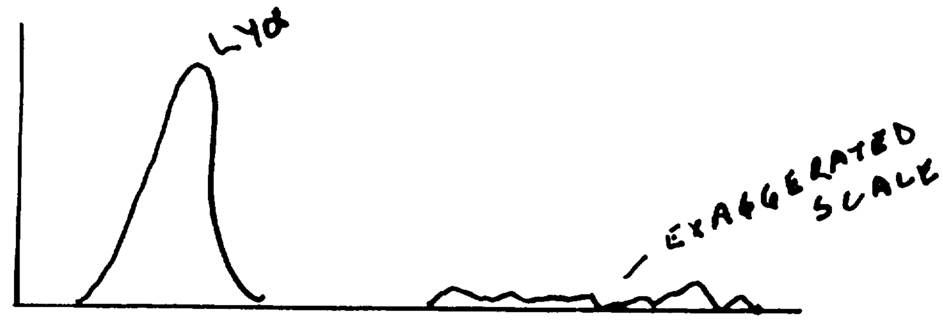
- Calibration is performed by simulating a point source of known wavelength with a measured intensity.

What the Detector Sees



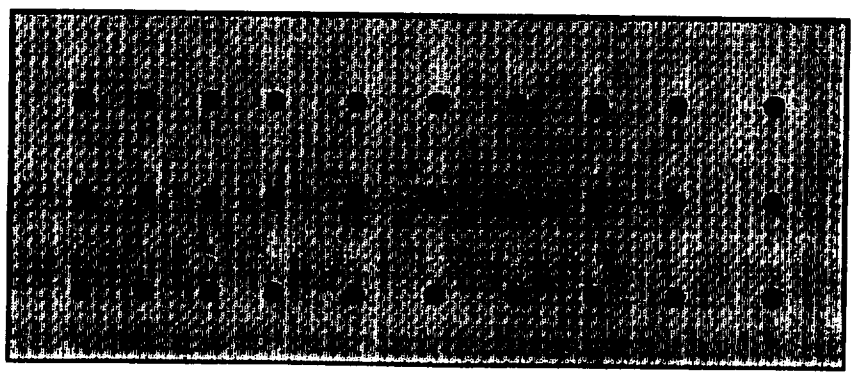
What We Have Measured So Far

- 1. Initial grating scatter measurements
  - Grating scatter < 0.08% of Ly α / channel in LBH wavelengths.
- 2. Shape of the scattered light.



Measurements 2

- Point Spread function of the SIS has been measured at 30 locations. The instrument optical performance is within design limits.



Measurements 3

- Primary and secondary detector sensitivities at all wavelengths, wide slit, nadir position of scan mirror.
- Sensitivity at two other mirror scan positions. (Not currently analyzed.)

Measurements 4

- Slit function (height and width) for wide, medium, and narrow slits. Height cannot be completely measured by the optical calibration facility, however.

SIS Measurements to be Made

- Sensitivity at the following wavelengths
  - 1175, 1200, 1216, 1250, 1275, 1300, 1325, 1350 Å
  - 1400, 1450, 1500, 1550, 1600, 1650, 1700, 1750, 1800, 1850 Å
  - Primary, secondary detector

Current Measurement Plan 2

- Pitch angles 0°, +3°, -3°, +6°, -6°
- Slit widths - wide, medium, narrow

Current Measurement Plan 3

- Mirror scan angle sensitivity
- For scan angle -72.8 -60, -40, -20, 0, +20, +40, +60°
  - For detector = primary, secondary
    - For λ = 1200 to 1800 by 100 Å

Current Measurement Plan 4

- *If* time permits the scan angle measurements will be repeated at -6°, -3°, +3°, +6°

CALIBRATION REQUIREMENTS (IN FLIGHT)

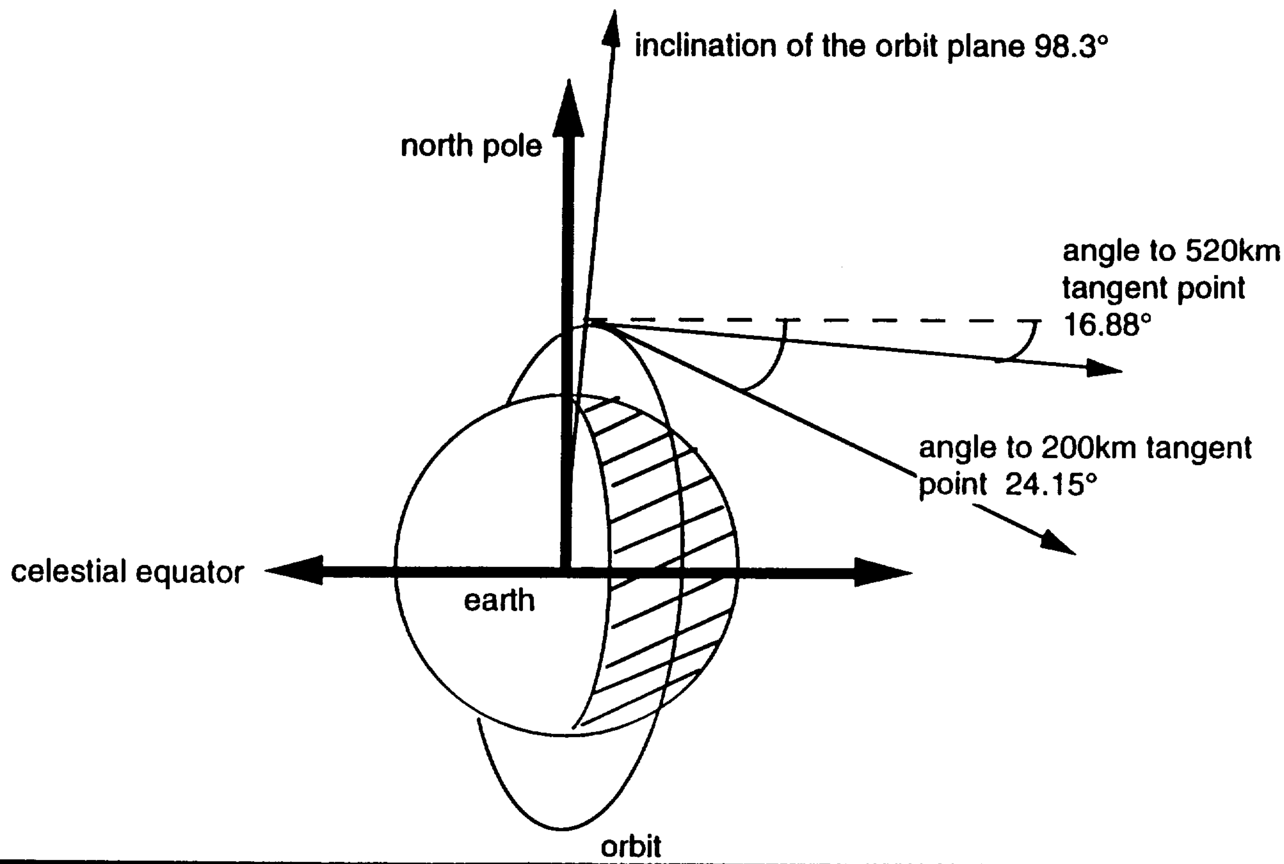
In-flight calibrations of GUVI must be performed.

- **The wavelength scale will change when a different slit is used.**

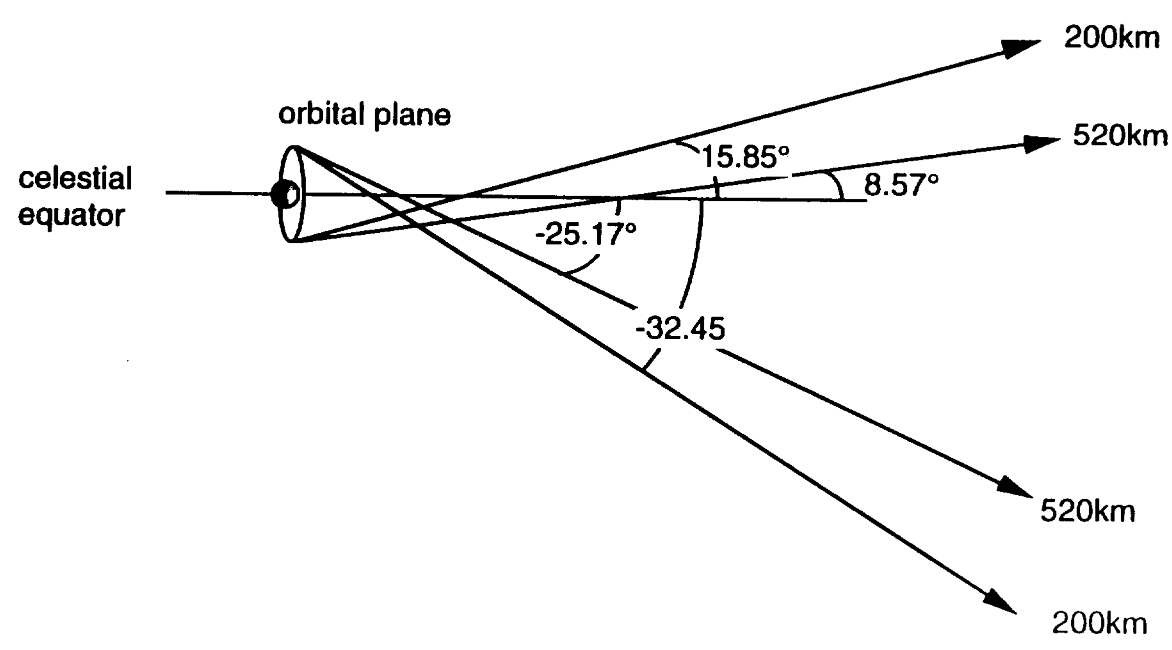
- Wavelength scale changes must be characterizable.
  - **The calibration must be determined in absolute terms on-orbit.**
- The ability to obtain unattenuated observations of stars is required to validate the Spectrographic Imager calibration.

C-2

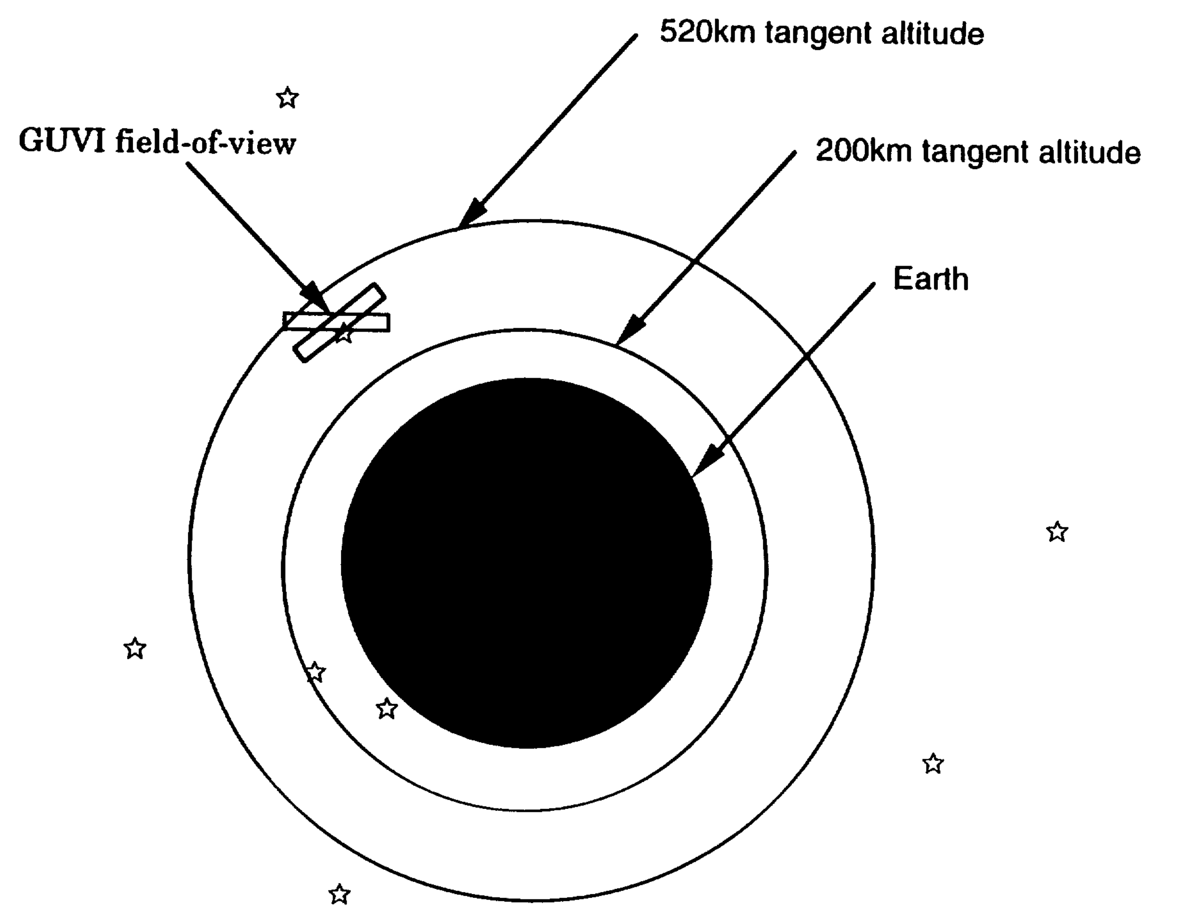
Line of Sight on the Celestial Sphere



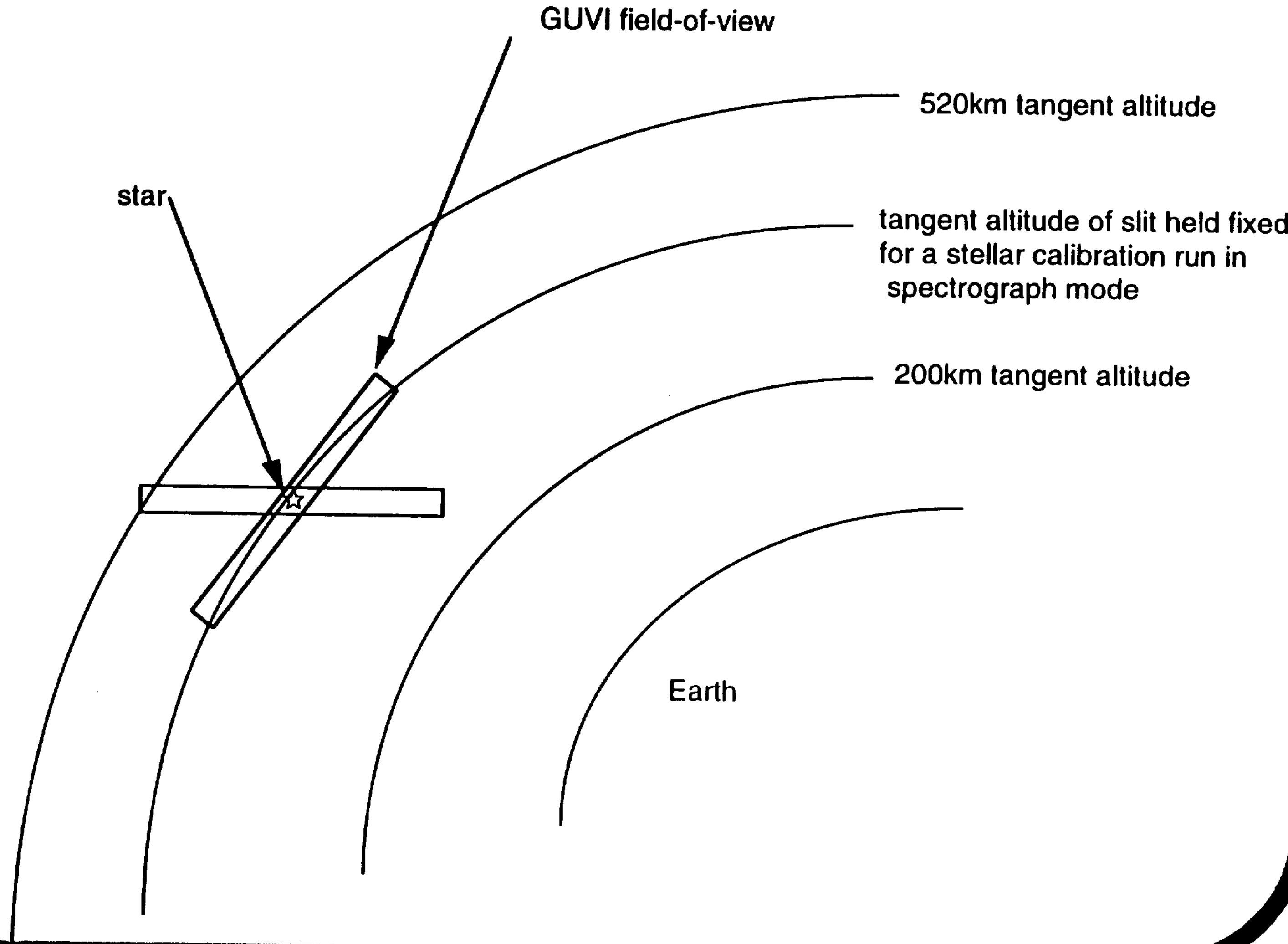
LOS at North and South Poles



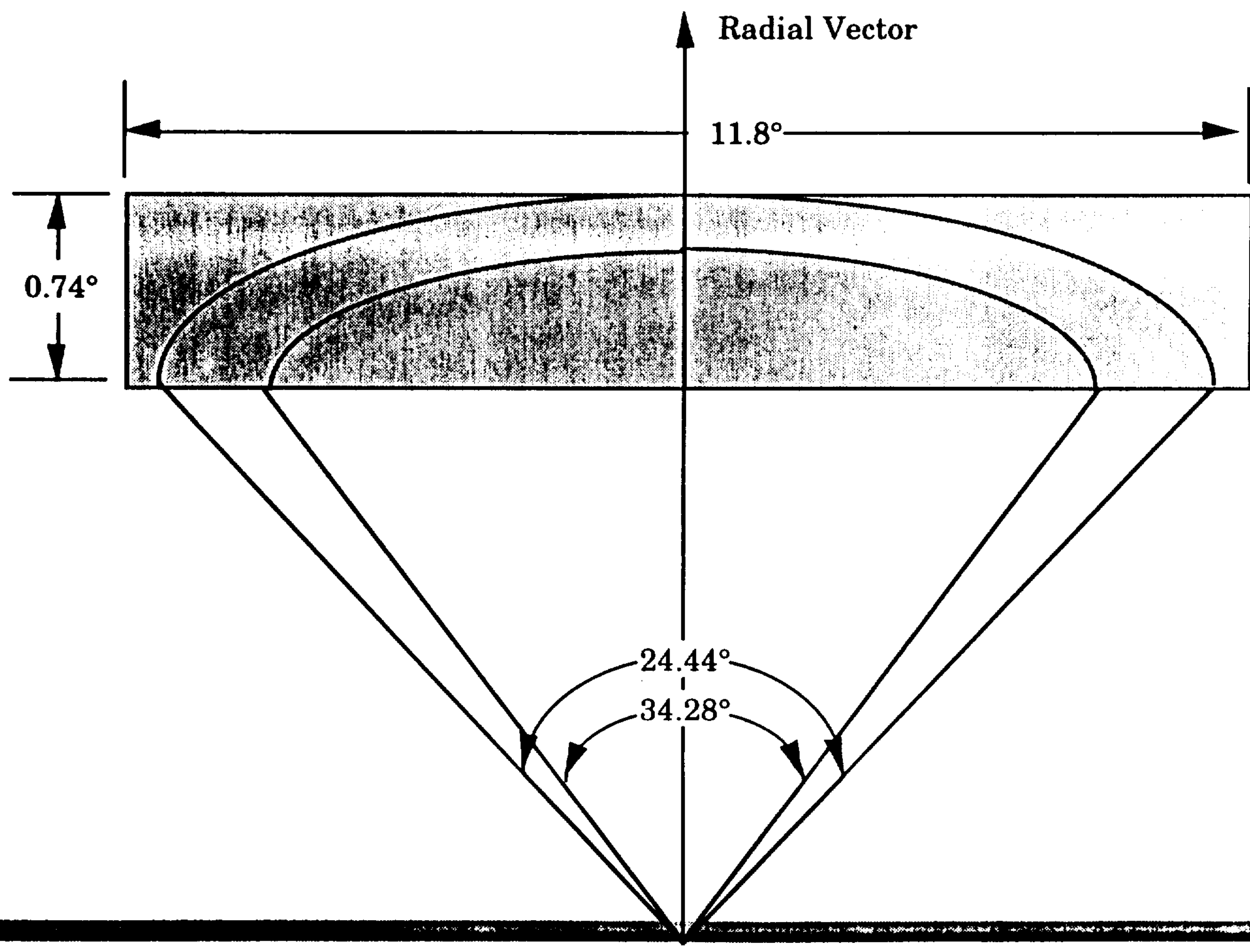
Star Calibration Sequence

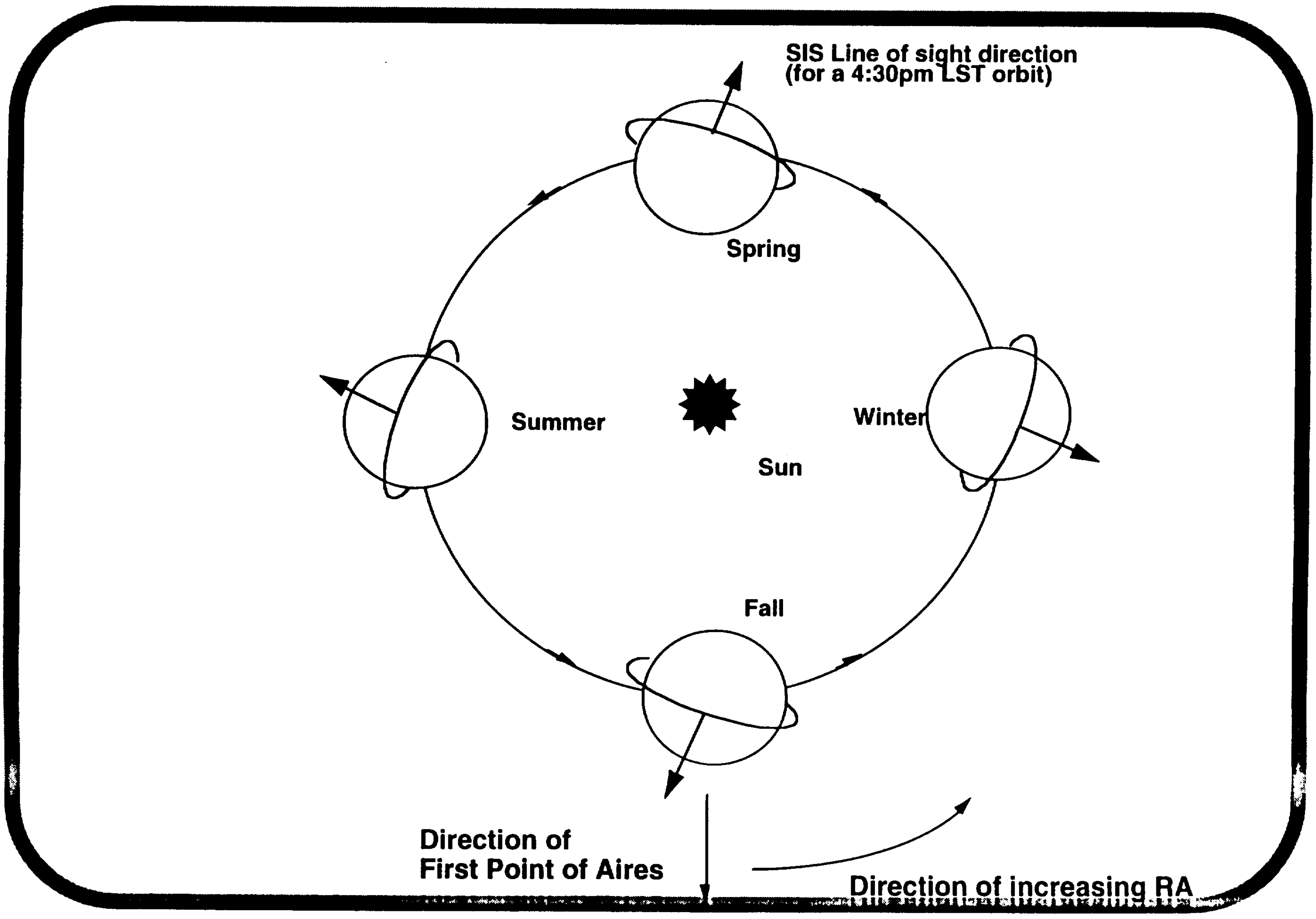


A Star in the FOV

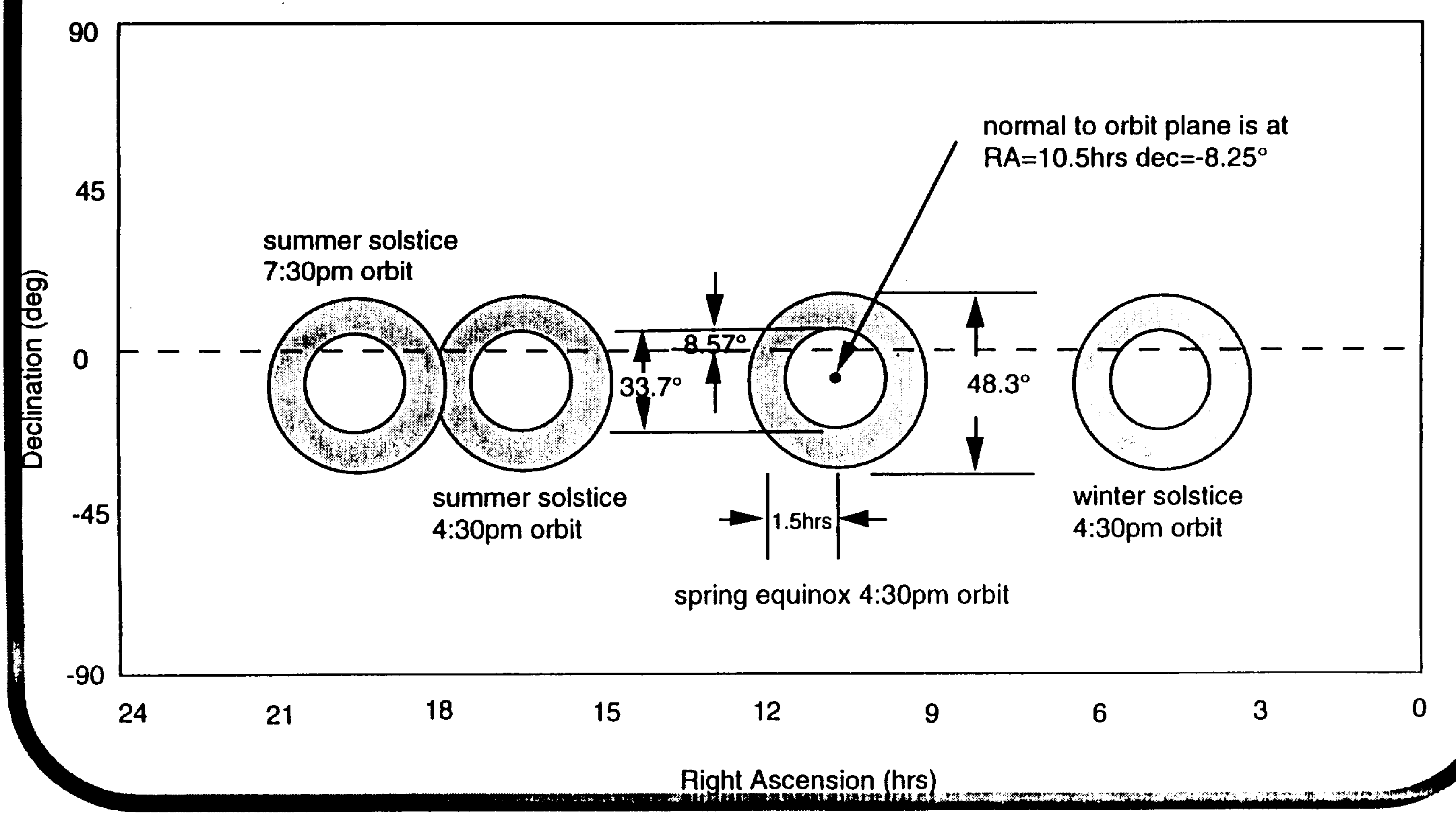


Star Motion thru FOV




SIS Line of sight direction
(for a 4:30pm LST orbit)
Spring
Summer
Sun
Winter
Fall
Direction of
First Point of Aires
Direction of increasing RA

Celestial Sphere Coverage



Limiting Spectral Magnitude (V)

Spectral Type	110	120	130	140	150	160	170	180
O5	6.1	10.1	12.0	12.1	11.5	10.5	9.3	7.6
O6	5.9	9.9	11.9	12.0	11.4	10.3	9.2	7.5
O7	5.6	9.7	11.7	11.8	11.2	10.2	9.1	7.4
O8	5.4	9.5	11.5	11.6	11.1	10.1	8.9	7.3
O9	5.1	9.3	11.3	11.4	10.9	9.9	8.8	7.1
B0	4.8	9.0	11.0	11.2	10.7	9.7	8.6	7.0
B1	4.5	8.7	10.8	11.0	10.5	9.5	8.5	6.8
B2	4.1	8.4	10.5	10.7	10.2	9.3	8.3	6.7
B3	3.7	8.0	10.1	10.4	10.0	9.1	8.0	6.5
B4	3.2	7.6	9.8	10.1	9.7	8.8	7.8	6.3
B5	2.8	7.2	9.4	9.8	9.4	8.6	7.6	6.0
B6	2.3	6.7	9.0	9.4	9.1	8.3	7.3	5.8
B7	1.7	6.3	8.6	9.1	8.7	8.0	7.0	5.6
B8	1.2	5.8	8.2	8.7	8.4	7.6	6.7	5.3
B9	0.6	5.3	7.7	8.2	8.0	7.3	6.4	5.0
A0	0.0	4.7	7.2	7.8	7.6	7.0	6.1	4.7

for 10% counting statistics in 10nm bin in .1s
(from R.E. Daniels)

Partial List of UV Calibration Stars

CATALOG	NAME	SPEC	V	R.A. (1950)	DEC (1950)	LIST
HD 66811	Zeta PUP	O5Ia	2.2	08 01 49.6	-39 51 41	IUE
HD 149757	Zeta OPH	O9V	2.6	16 34 24.1	-10 28 03	IUE, ST
HD 214680	10 LAC	O9V	4.9	22 37 00.8	+38 47 22	IUE, ST
HD 38666	Mu COL	O9V	5.2	05 44 08.4	-32 19 27	IUE, ST
HD 93521		O9Vp	7.1	10 45 33.6	+37 50 04	IUE, ST
BD+75 325		O5pvar	9.6	08 04 43.2	+75 06 48	IUE, ST
BD+28 4211		Op	10.5	21 48 57.4	+28 37 34	IUE, ST
HD 10144	Alpha ERI	B3Vpe	0.5	01 35 51.2	-57 29 25	IUE
HD 35468	Gam ORI	B2III	1.6	05 22 26.9	+06 18 22	IUE
HD 120315	Eta UMA	B3V	1.9	13 45 34.3	+49 33 44	IUE, ST*
HD 121263		B2IV	2.6	13 52 24.5	-47 02 35	IUE
HD 149438	Tau SCO	B0V	2.8	16 32 45.9	-28 06 51	IUE
HD 24760	Eps PER	B0V	2.9	03 54 29.5	+39 52 02	IUE
HD 32630	Eta AUR	B3V	3.2	05 03 00.2	+41 10 08	IUE, ST
HD 3360	Zeta CAS	B2IV	3.5	00 34 10.3	+53 37 19	IUE, ST
HD 142669	Rho SCO	B2IV-V	3.9	15 53 47.5	-29 04 11	IUE
HD 34816	Lambda LEP	B0IV	4.3	05 17 16.2	-13 13 37	IUE, ST
HD 74280	Eta HYA	B3V	4.3	08 40 36.7	+03 34 46	IUE
HD 60753		B2III	6.7	07 32 08.1	-50 28 29	+IUE, ST
HD 45057		B3V	6.9	06 21 14.5	-53 18 31	IUE
HD 197637		B3	7.0	20 38 01.8	+79 15 15	IUE

see CDR Action Item 01a,
C/C Plan, TEMP and OPS Plan for more