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
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PRINCIPAL INVESTIGATOR
ANDREW B CHRISTENSEN

AEROSPACE CORPORATION

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

Unclas
GUVI
GUVI INVESTIGATOR TEAM

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D. E. Anderson
G. Crowley

Applied Physics Laboratory
The Johns Hopkins University

S. Avery
Department of Engineering
University of Colorado
• Ground state transitions for N₂, 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)
  N₂LBH(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
GEOPHYSICAL REGIONS FOR STUDY

- Dayside
  * Constituent Densities: N₂, O₂, 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
- Composition
- 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 SEE EUV measurements using the SEE instrument, respectively.

- Study the occurrence, structure, and distribution of Polar Mesospheric Clouds.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea-level</td>
<td>100 m above mean sea level</td>
<td>100.40 m</td>
<td></td>
</tr>
</tbody>
</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)
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, $N_{max}$, TEC

values of auroral quantities:

- $Q_e$, $Q_p$, $E_0$, $\Sigma_p$

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
Altitude range for atmospheric state variables derived from GUVI observations.
Altitude range for energy and dynamical quantities derived from GUVI observations. $Q$ is the energy flux of precipitating auroral particles, $\Sigma_p$ is height-integrated Pedersen conductivity, $e^-$ and $p^+$ are fluxes of electrons and protons.
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 km²
- Dayside - 100 x 100 km²
- Nightside - 200 X 200 km²

Temporal Resolution: Mirror scan time: 13.23s forward, 1.77s flyback, 15 s full scan, 71.5 ms/pix
<table>
<thead>
<tr>
<th>NAME</th>
<th>COLORS</th>
<th>SLIT</th>
<th>SCAN</th>
<th>COMMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode 0: Dayside</td>
<td>5 wavelength regions</td>
<td>Standard slit, fixed</td>
<td>140° full</td>
<td>Terminator crossing flag needed</td>
</tr>
<tr>
<td>Mode 1: Nightside</td>
<td>5 wavelength regions</td>
<td>Wide slit, fixed</td>
<td>140° full</td>
<td>Slit adjustment, and color changes at flag,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>if requested</td>
</tr>
<tr>
<td>Mode 2: Star Calibration</td>
<td>Full wavelength scan</td>
<td>All slits in sequence</td>
<td>Fixed scan mirror, above horizon</td>
<td>Time tagged</td>
</tr>
<tr>
<td>Mode 3: Wavelength Calibration</td>
<td>Full wavelength scan</td>
<td>All slits in sequence</td>
<td>Fixed scan mirror, below horizon</td>
<td>Time Tagged</td>
</tr>
<tr>
<td>Mode 4: Sun Avoidance</td>
<td>5 wavelength regions</td>
<td>Standard slit, fixed</td>
<td>±60 °</td>
<td>Time Tagged</td>
</tr>
</tbody>
</table>

**THE AEROSPACE CORPORATION**
GUVI layout diagram. The optical components, scan mirror range of motion, slit mechanism, primary and secondary detectors, and spectral dispersion are shown.
# GUVI
## GUVI ACCURACY ESTIMATES
### DAYSIDE SCIENCE

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>SPATIAL SCALE</th>
<th>ALTITUDE</th>
<th>PRECISION (view @ 300km, 75° SZA)</th>
<th>INFERRED QUANTITIES</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIMB</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O1(135.6)</td>
<td></td>
<td>130 - 300 km</td>
<td>± 3 %</td>
<td>N₂O₂O</td>
<td>± 15 %</td>
</tr>
<tr>
<td>LBH (1)</td>
<td>250 km Horizontal</td>
<td></td>
<td>± 7 %</td>
<td>Solar EUV</td>
<td>± 10-15 %</td>
</tr>
<tr>
<td>LBH (2)</td>
<td></td>
<td></td>
<td>±10%</td>
<td>Temp</td>
<td>± 8 %</td>
</tr>
<tr>
<td>HI(121.6)</td>
<td>100 x 100 km²</td>
<td>110 - 300 km</td>
<td>± 1 %</td>
<td>H</td>
<td>± 10 %</td>
</tr>
<tr>
<td><strong>DISK</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O1(135.6)</td>
<td>100 x 100 km²</td>
<td>130 - 300 km</td>
<td>± 3 %</td>
<td>[O]/[N₂] column abundance</td>
<td>± 5 %</td>
</tr>
<tr>
<td>LBH (1)</td>
<td></td>
<td></td>
<td>± 5 %</td>
<td>N₂O₂O</td>
<td>± 20 %</td>
</tr>
<tr>
<td>HI(121.6)</td>
<td>100 x 100 km²</td>
<td>110 - 300 km</td>
<td>± 1 %</td>
<td>H (2 model parameters)</td>
<td>±10 %</td>
</tr>
</tbody>
</table>

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## GUVI ACCURACY ESTIMATES

### LOW LATITUDE NIGHTSIDE SCIENCE

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>SPATIAL SCALE</th>
<th>ALTITUDE</th>
<th>PRECISION</th>
<th>INFERRED QUANTITIES</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>OI(135.6)</td>
<td>100 x 100 km²</td>
<td>Lower F Region</td>
<td>± 5%</td>
<td>$N_{\text{max}}, H_{\text{max}}$</td>
<td>± 9%</td>
</tr>
<tr>
<td>OI(130.4) (radiative recombination emission)</td>
<td>100 x 100 km²</td>
<td>100 - 300 km</td>
<td>± 11%</td>
<td>Total Electron Content (TEC)</td>
<td>± 22%</td>
</tr>
<tr>
<td>OI(130.4) OI(135.6) N₂(LBH) (energetic Particle Precipitation)</td>
<td>100 x 100 km²</td>
<td>100 - 300 km</td>
<td>± 11%</td>
<td>Energetic Particle Flux</td>
<td>TBD (Cross section uncertainties)</td>
</tr>
</tbody>
</table>

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**THE AEROSPACE CORPORATION**
### GUVI
### ACCURACY ESTIMATES

#### AURORAL ZONE SCIENCE

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>SPATIAL SCALE</th>
<th>ALTITUDE</th>
<th>PRECISION (Class II Aurora)</th>
<th>INFERRED QUANTITIES</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>OI(135.6)</td>
<td>10 x 10 km²</td>
<td>100 - 150 KM</td>
<td>± 7%</td>
<td>Qₜ (Ergs/cm²/s)</td>
<td>± 20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>± 9%</td>
<td>E₀ (Kev)</td>
<td>± 25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>±13%</td>
<td>Σₚ (Mho)</td>
<td>± 30%</td>
</tr>
<tr>
<td>LBH (1)</td>
<td></td>
<td></td>
<td>± 9% *</td>
<td>Qᵣ protons</td>
<td>± 21%</td>
</tr>
<tr>
<td>LBH (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HI(121.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 0.1 ergs/cm²/s proton precipitation flux
**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/N₂
(2-D Maps of column abundance)

ΔN₂, ΔO₂,
ΔO₂,ΔT,ΔH
(Altitude profiles on the limb)

ΔFₑₑᵤᵥ
(Change in integrated solar flux)

**Nightside**

n₁
(Altitude profile on limb)

Nₘₐₓ, Hₘₐₓ
(Along limb track)

TEC
(Line of sight along track)

**Auroral (day and night)**

Q, E₀
(2-D maps of electron and proton energy fluxes and characteristic energy)

Auroral boundary locations

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

nₑ in E-layer
(Along track altitude profile)
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
CONTAMINATION

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

Strategy:  During I&T purge with research grade N\textsubscript{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 \text{ 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
VIEW A-A
(MOTOR RADIATOR NOT SHOWN FOR CLARITY)
##GU VI SPECIFICATIONS

###MASS

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIS Housing</td>
<td>6.4</td>
</tr>
<tr>
<td>SIS Electronics</td>
<td>1.2</td>
</tr>
<tr>
<td>DHVPS</td>
<td>1.0</td>
</tr>
<tr>
<td>FPE #1</td>
<td>0.8</td>
</tr>
<tr>
<td>FPE #2</td>
<td>0.8</td>
</tr>
<tr>
<td>ECU</td>
<td>7.0</td>
</tr>
<tr>
<td>Harness</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>19.2</strong></td>
</tr>
</tbody>
</table>

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

VOLUME

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume (LxWxH cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIS Housing</td>
<td>48 x 24 x 21 (30 H when cover open)</td>
</tr>
<tr>
<td>SIS Electronics</td>
<td>25 x 17 x 6</td>
</tr>
<tr>
<td>DHVPS</td>
<td>15 x 10 x 6</td>
</tr>
<tr>
<td>FPE #1</td>
<td>15 x 6 x 12</td>
</tr>
<tr>
<td>FPE #2</td>
<td>15 x 6 x 12</td>
</tr>
<tr>
<td>ECU</td>
<td>38 x 23 x 20</td>
</tr>
</tbody>
</table>

SIS Subsystem Envelope 76 x 36 x 21 (for layout shown earlier)

LAYOUT RESTRICTIONS

<table>
<thead>
<tr>
<th>Component</th>
<th>Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIS Electronics</td>
<td>within 15 cm of SIS scan motor</td>
</tr>
<tr>
<td>DHVPS</td>
<td>within 30 cm of both tubes</td>
</tr>
<tr>
<td>FPE #1</td>
<td>within 10 cm of tube #1</td>
</tr>
<tr>
<td>FPE #2</td>
<td>within 10 cm of tube #2</td>
</tr>
<tr>
<td>ECU</td>
<td>within 150 cm of SIS subsystem</td>
</tr>
</tbody>
</table>
**GUVI SPECIFICATIONS**

**POWER**

<table>
<thead>
<tr>
<th></th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Average</td>
<td>24</td>
</tr>
<tr>
<td>Operating Peak</td>
<td>29</td>
</tr>
<tr>
<td>Standby</td>
<td>4</td>
</tr>
</tbody>
</table>

No thermal control power included.

**TEMPERATURE**

<table>
<thead>
<tr>
<th></th>
<th>Operating</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIS</td>
<td>-20°C to +40°C</td>
<td>-29°C to +50°C</td>
</tr>
<tr>
<td>ECU</td>
<td>-24°C to +61°C</td>
<td>-29°C to +66°C</td>
</tr>
</tbody>
</table>
# GUVI SPECIFICATIONS

## ALTITUDE

<table>
<thead>
<tr>
<th>Operating</th>
<th>400 km to 600 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred</td>
<td>600 km</td>
</tr>
</tbody>
</table>

## DATA RATE

<table>
<thead>
<tr>
<th></th>
<th>Rate (kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>7.8</td>
</tr>
<tr>
<td>Housekeeping</td>
<td>0.1</td>
</tr>
</tbody>
</table>

(for 600 km orbit)

## DATA FRAME

<table>
<thead>
<tr>
<th></th>
<th>180 cross track x 8 along track pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image Size</td>
<td>180 cross track x 8 along track pixels</td>
</tr>
<tr>
<td>Colors</td>
<td>5</td>
</tr>
<tr>
<td>Pixel Size</td>
<td>8 bits</td>
</tr>
<tr>
<td>Frame Period</td>
<td>15 sec</td>
</tr>
</tbody>
</table>

(for 600 km orbit)
GUVI SPECIFICATIONS

FIELD OF VIEW

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

ALIGNMENT

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Placement</td>
<td>1.0 deg</td>
</tr>
<tr>
<td>Knowledge</td>
<td>0.3 deg</td>
</tr>
<tr>
<td>Jitter</td>
<td>0.4 deg / sec</td>
</tr>
<tr>
<td>Stability</td>
<td>1.0 deg / sec</td>
</tr>
</tbody>
</table>

UNCOMPENSATED MOMENTUM

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Mirror</td>
<td>0.002 inch-lb-sec</td>
</tr>
<tr>
<td>Cover</td>
<td>4.5 inch-lb-sec</td>
</tr>
</tbody>
</table>
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
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)**

<table>
<thead>
<tr>
<th>Function</th>
<th>Digitizes Tube Pulse Heights for Event Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contains Pre-Amplifiers and A/D Converters</td>
</tr>
<tr>
<td></td>
<td>Maximum count rate = 200 k counts/sec</td>
</tr>
<tr>
<td></td>
<td>Two Units for Redundancy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heritage</th>
<th>SSUSI Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition</td>
<td>APL Build</td>
</tr>
</tbody>
</table>

| Changes                          | None Planned                                    |
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

- **Scanning Imaging Spectrograph**
  - Scan Mirror
  - Detector
  - 160 spectral elements
  - 16 spatial elements

**Scan Modes**
- **Along Track Motion**
  - 124.8° Cross Track Scan
  - 156 pixels (horizon to horizon)

**Scan Details**
- **Line Scan**
  - 16 pixels
- **9.6° Cross Track Scan**
  - 24 pixels
- **11.8° FOV**
<table>
<thead>
<tr>
<th><strong>GUVI OPTICAL SPECIFICATIONS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instantaneous Field of View</strong></td>
</tr>
<tr>
<td>narrow slit</td>
</tr>
<tr>
<td>nominal slit</td>
</tr>
<tr>
<td>wide slit</td>
</tr>
<tr>
<td><strong>Pixel Field of View</strong></td>
</tr>
<tr>
<td>narrow slit</td>
</tr>
<tr>
<td>nominal slit</td>
</tr>
<tr>
<td>wide slit</td>
</tr>
<tr>
<td><strong>Scanned Field of View</strong></td>
</tr>
<tr>
<td>Limb</td>
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<td>Earth</td>
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<td><strong>Spatial Resolution at Nadir</strong></td>
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<td>600 km orbit</td>
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<tr>
<td><strong>Spectral Range</strong></td>
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<td>115 nm to 180 nm</td>
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<td><strong>Spectral Resolution</strong></td>
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<tr>
<td>nominal slit</td>
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<tr>
<td>wide slit</td>
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GUVI DETECTOR SUBSYSTEM

DHVPS → To ECU

HV Bias

MCP

TUBE

W

S

I

PRE-AMP

PRE-AMP

PRE-AMP

FAST-AMP

FPE

ADC

ADC

ADC

TIMING

DPU Board

Latch

Processor

CPU Interface

CPU Bus
GUVI FLIGHT SOFTWARE REQUIREMENTS

Detector Processor Unit (DPU)

Processor: Harris RTX 2000
Language: Forth

Module 1:
Function: Monitor
Memory: Stored in PROM on DPU Board
Size: 4k bytes

Module 2:
Function: Event Processing
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

<table>
<thead>
<tr>
<th></th>
<th>Flight</th>
<th>GSE</th>
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<td>Preferred Parts Grade</td>
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</tbody>
</table>
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
<table>
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<tr>
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### GUVI TOTAL COST

#### PHASE C/D

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<td>Jan-Sep</td>
<td>Oct-Dec</td>
<td>Jan-Sep</td>
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<td>GUVI Total Cost</td>
<td>963</td>
<td>2199</td>
<td>1280</td>
<td>1619</td>
<td>237</td>
<td>515</td>
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</table>
Flight Software (Telemetry Processor)

- Event driven; operations scheduled at 10 msec interval timeout
- Flight software written in C and Assembler (where time criticality 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
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
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

MAC → IEEE-488

GESPAC

GSE → Detector Processor Simulation

Power Supply

1773 or RS422

Main Power

Aerospace Boards

ECU
GSE Configuration -- Stage 2

- MAC
  - IEEE-488
- GES PAC
  - GSE
  - Power Supply
- Spectrograph
- 1773 or RS422
- Main Power
- Aerospace Boards
- ECU
GSE Configuration -- Stage 3

- MAC
- IEEE-488
- GESPAC
- GSE
- Power Supply
- 1773 or RS422
- Main Power
- Spectrograph
- APL PC
- RS-232
- APL Calibration Equipment
- Aerospace Boards
- ECU
GSE Configuration -- Stage 4

GUVI

TIMED Spacecraft

Spacecraft Checkout System

MAC

IEEE-488

GSE
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

6/92 1/93 10/93 1/94 5/94 10/94 1/95 4/95

Algorithm Development

Software Development

Day

Night

Gridding

Junior

Senior

Preliminary Software Requirements Specification

Software Specifications Review

Informal Status Review

Preliminary Design Review

Final SRS

Informal Status Review

Critical Design Review

Final STR, SDD

Final Software Users Manual

Pre. Software Users Manual

Version Description Document

Science Interpretation Manual

Final Software Test Plan and Software Test Report

Functional Configuration Audit

Test and Integration at SFC

Deliver of Build 1

Pre. Software Design Document and Software Test Plan

Coding

Unit testing

Integration and CSCI testing

8/94

Final Software Users Manual

Science Product Spec. (source code + SDD)
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 20 minutes 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
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 occurrence in time and space.

Existing 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 3wmi including testing and documentation)
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

SAMPEX Block Diagram

- HILT
- LEICA
- MAST
- PET
- MAST/PET Low Voltage Power Supply (LVPS)
- Small Explorer Data System (SEDS)
- Power Distrib. & Pyro Control Unit (PDPCU)

--- LEGEND ---
CONTROL BUS
DATA BUS
POWER BUS
INSTRUMENT DPU

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

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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

<table>
<thead>
<tr>
<th>Calibration Test</th>
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<th>Prelim</th>
<th>Pre-env</th>
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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

-6° Pitch +6°

λ
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 $\lambda = 1200$ to 1800 by 100 Å
Current Measurement Plan 4

• *If* time permits the scan angle measurements will be repeated at \(-6^\circ, -3^\circ, +3^\circ, +6^\circ\)
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.
Line of Sight on the Celestial Sphere

- Inclination of the orbit plane: 98.3°
- Angle to 520km tangent point: 16.88°
- Angle to 200km tangent point: 24.15°
LOS at North and South Poles

Orbital plane

Celestial equator

200km

520km

15.85°

8.57°

-25.17°

-32.45°

520km

200km
Star Calibration Sequence

520km tangent altitude

GIJ field-of-view

200km tangent altitude

Earth

GUVI field-of-view
A Star in the FOV

GUVI field-of-view

520km tangent altitude

tangent altitude of slit held fixed for a stellar calibration run in spectrograph mode

200km tangent altitude

Earth
Star Motion thru FOV

Radial Vector

11.8°

0.74°

24.44°

34.28°
SIS Line of sight direction (for a 4:30pm LST orbit)

Spring

Summer

Winter

Fall

Direction of First Point of Aires

Direction of increasing RA
Celestial Sphere Coverage

- Summer solstice: 7:30pm orbit
- Winter solstice: 4:30pm orbit
- Spring equinox: 4:30pm orbit

Normal to orbit plane is at RA=10.5hrs dec=-8.25°
# Limiting Spectral Magnitude (V)

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For 10% counting statistics in 10nm bin in .1
drawn by R.E. Daniels.
**Partial List of UV Calibration Stars**

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