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
GUVI INVESTIGATOR TEAM

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

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Department of Engineering
University of Colorado

D. J. Strickland
Computational Physics, Inc.
• 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)
• 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: N₂, O₂, O, H
  * Solar EUV Flux: Integral λ ≤ 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 EUV measurements using the SEE instrument, respectively.

Study the occurrence, structure, and distribution of Polar Mesospheric Clouds.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Temperature</td>
<td>130°F 40°C</td>
<td></td>
</tr>
<tr>
<td>Max Temperature</td>
<td>121°F 50°C</td>
<td></td>
</tr>
<tr>
<td>Min Temperature</td>
<td>112°F 45°C</td>
<td></td>
</tr>
<tr>
<td>Mean Precipitation</td>
<td>3.5 in 90 mm</td>
<td></td>
</tr>
<tr>
<td>Max Precipitation</td>
<td>7.1 in 180 mm</td>
<td></td>
</tr>
<tr>
<td>Min Precipitation</td>
<td>0.0 in 0 mm</td>
<td></td>
</tr>
<tr>
<td>Mean Humidity</td>
<td>72%</td>
<td></td>
</tr>
<tr>
<td>Max Humidity</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>Min Humidity</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Mean Wind Speed</td>
<td>10 mph</td>
<td></td>
</tr>
<tr>
<td>Max Wind Speed</td>
<td>35 mph</td>
<td></td>
</tr>
<tr>
<td>Min Wind Speed</td>
<td>0 mph</td>
<td></td>
</tr>
<tr>
<td>Mean Wind Gust Speed</td>
<td>25 mph</td>
<td></td>
</tr>
<tr>
<td>Max Wind Gust Speed</td>
<td>60 mph</td>
<td></td>
</tr>
<tr>
<td>Min Wind Gust Speed</td>
<td>0 mph</td>
<td></td>
</tr>
</tbody>
</table>

**Environmental Parameters:**
- Mean Temperature
- Max Temperature
- Min Temperature
- Mean Precipitation
- Max Precipitation
- Min Precipitation
- Mean Humidity
- Max Humidity
- Min Humidity
- Mean Wind Speed
- Max Wind Speed
- Min Wind Speed
- Mean Wind Gust Speed
- Max Wind Gust Speed
- Min Wind Gust Speed

**Scientific Parameter:**
- Mean Temperature
- Max Temperature
- Min Temperature
- Mean Precipitation
- Max Precipitation
- Min Precipitation
- Mean Humidity
- Max Humidity
- Min Humidity
- Mean Wind Speed
- Max Wind Speed
- Min Wind Speed
- Mean Wind Gust Speed
- Max Wind Gust Speed
- Min Wind Gust Speed

**Scientific Data:**
- Mean Temperature
- Max Temperature
- Min Temperature
- Mean Precipitation
- Max Precipitation
- Min Precipitation
- Mean Humidity
- Max Humidity
- Min Humidity
- Mean Wind Speed
- Max Wind Speed
- Min Wind Speed
- Mean Wind Gust Speed
- Max Wind Gust Speed
- Min Wind Gust Speed

**Legend:**
- Temperature (°F/°C)
- Precipitation (in/mm)
- Humidity (%)
- Wind Speed (mph)
- Wind Gust Speed (mph)
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, O₂, O, N₂, H, O/N₂ column, Nmax, TEC

values of auroral quantities:

- Qₑ, Qₚ, Eₒ, Σₚ

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.
### GUVI

**SPATIAL REQUIREMENTS SUMMARY**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude Resolution on Limb</td>
<td>IFOV: 0.37°/15 km, Spacing: 0.5°/20 km, @ 600 km orbital altitude</td>
</tr>
<tr>
<td>Altitude Coverage on Limb</td>
<td>100 to 500 km</td>
</tr>
<tr>
<td>Spatial Coverage on Disk</td>
<td>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</td>
</tr>
<tr>
<td>Along Track: IFOV: 11.8°/126 km, 15 pixels (8 km/pix in nadir)</td>
<td></td>
</tr>
<tr>
<td>Spatial Resolution on Disk (Post processing)</td>
<td>Aurora - 20 x 20 km²</td>
</tr>
<tr>
<td>Dayside - 100 x 100 km²</td>
<td></td>
</tr>
<tr>
<td>Nightside - 200 X 200 km²</td>
<td></td>
</tr>
<tr>
<td>Temporal Resolution</td>
<td>Mirror scan time: 13.23s forward, 1.77s flyback, 15 s full scan, 71.5 ms/pix</td>
</tr>
</tbody>
</table>

---

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<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</td>
<td>Standard slit, fixed</td>
<td>140° full</td>
<td>Terminator crossing flag needed</td>
</tr>
<tr>
<td></td>
<td>regions</td>
<td></td>
<td></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 1: Nightside</td>
<td>5 wavelength</td>
<td>Wide slit, fixed</td>
<td>140° full</td>
<td>Time tagged</td>
</tr>
<tr>
<td></td>
<td>regions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode 2: Star</td>
<td>Full wavelength</td>
<td>All slits in</td>
<td>Fixed scan</td>
<td>Time Tagged</td>
</tr>
<tr>
<td>Calibration</td>
<td>scan</td>
<td>sequence</td>
<td>mirror, above</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>horizon</td>
<td></td>
</tr>
<tr>
<td>Mode 3: Wavelength</td>
<td>Full wavelength</td>
<td>All slits in</td>
<td>Fixed scan</td>
<td>Time Tagged</td>
</tr>
<tr>
<td>Calibration</td>
<td>scan</td>
<td>sequence</td>
<td>mirror, below</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>horizon</td>
<td></td>
</tr>
<tr>
<td>Mode 4: Sun</td>
<td>5 wavelength</td>
<td>Standard slit, fixed</td>
<td>±60 °</td>
<td>Time Tagged</td>
</tr>
<tr>
<td>Avoidance</td>
<td>regions</td>
<td></td>
<td></td>
<td></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>OI(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>
</tbody>
</table>

| **DISK** |               |          |                                   |                     |          |
| OI(135.6) | 100 x 100 km² | 130 - 300 km | ± 3%                             | [O]/[N₂] column abundance | ± 5%     |
| LBH (1)   |               |          | ± 5%                             | N₂O₂O               | ± 20%    |
| HI(121.6) | 100 x 100 km² | 110 - 300 km | ± 1%                             | H (2 model parameters) | ±10%     |

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<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&lt;sub&gt;max&lt;/sub&gt;, H&lt;sub&gt;max&lt;/sub&gt;</td>
<td>± 9%</td>
</tr>
<tr>
<td>OI(130.4) (radiative recombination emission)</td>
<td></td>
<td></td>
<td></td>
<td>Total Electron Content (TEC)</td>
<td>± 22%</td>
</tr>
<tr>
<td>OI(130.4)</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>
<tr>
<td>OI(135.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N₂(LBH) (energetic Particle Precipitation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# 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>$Q_e$ (Ergs/cm²/s)</td>
<td>± 20%</td>
</tr>
<tr>
<td>LBH (1)</td>
<td></td>
<td></td>
<td>± 9%</td>
<td>$E_o$ (Kev)</td>
<td>± 25%</td>
</tr>
<tr>
<td>LBH (2)</td>
<td></td>
<td></td>
<td>±13%</td>
<td>$\Sigma_p$ (Mho)</td>
<td>± 30%</td>
</tr>
<tr>
<td>HI(121.6)</td>
<td></td>
<td></td>
<td>± 9% *</td>
<td>$Q_{protons}$</td>
<td>± 21%</td>
</tr>
</tbody>
</table>

* 0.1 ergs/cm²/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)**

<table>
<thead>
<tr>
<th>Dayside</th>
<th>Nightside</th>
<th>Auroral (day and night)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O/N₂</td>
<td>n_l</td>
<td>Q, E₀</td>
</tr>
<tr>
<td>(2-D Maps of column abundance)</td>
<td>(Altitude profile on limb)</td>
<td>(2-D maps of electron and proton energy fluxes and characteristic energy)</td>
</tr>
<tr>
<td>ΔN₂, ΔO₂, ΔO,ΔT,ΔH</td>
<td>N_max, H_max</td>
<td>Auroral boundary locations</td>
</tr>
<tr>
<td>(Altitude profiles on the limb)</td>
<td>(Along limb track)</td>
<td>(2-D maps of height integrated Pedersen conductivity)</td>
</tr>
<tr>
<td>ΔFₑᵤᵥ</td>
<td>TEC</td>
<td>nₑ in E-layer</td>
</tr>
<tr>
<td>(Change in integrated solar flux)</td>
<td>(Line of sight along track)</td>
<td>(Along track altitude profile)</td>
</tr>
</tbody>
</table>
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
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 (≤ 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
VIEW A-A
(MOTOR RADIATOR NOT SHOWN FOR CLARITY)
**GUVI 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</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

Operating  400 km to 600 km
Preferred  600 km

DATA RATE

<table>
<thead>
<tr>
<th>Rate  (kbps)</th>
<th>Science</th>
<th>7.8</th>
<th>(for 600 km orbit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housekeeping</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DATA FRAME

<table>
<thead>
<tr>
<th>Image Size</th>
<th>180 cross track x 8 along track pixels</th>
</tr>
</thead>
<tbody>
<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>
GUVI SPECIFICATIONS

FIELD OF VIEW

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

ALIGNMENT

<table>
<thead>
<tr>
<th></th>
<th>Value</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

<table>
<thead>
<tr>
<th></th>
<th>Value</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>
**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
<table>
<thead>
<tr>
<th>Function:</th>
<th>Provides High Voltage Power for Detector Tube</th>
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</thead>
<tbody>
<tr>
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<td>Adjustable Single High Voltage Output</td>
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<td>Two Units for Redundancy</td>
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<td>Subcontract</td>
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<td>Changes:</td>
<td>None Planned</td>
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</table>
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

Along Track Motion

124.8° Cross Track Scan
156 pixels
(horizon to horizon)

16 pixels

9.6° Cross Track Scan
24 pixels

11.8° FOV

Linear Scan
## GUVI Optical Specifications

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<th>along track</th>
<th>step resolution</th>
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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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<td><strong>Spectral Range</strong></td>
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<td>wide slit</td>
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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

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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
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8/1/94
## GUVI TOTAL COST

### PHASE C/D

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<tr>
<td>GUVI Total Cost</td>
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<td>2199</td>
<td>1280</td>
<td>1619</td>
<td>237</td>
<td>515</td>
<td>6813</td>
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</tbody>
</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
ECU Interface Simulator

- Buffer Electronics per ICD
- A/D Converter
- PROM
- Interface ACTEL Gate Array
- 80C186 uProc
- Parallel Port Interface Logic
- RAM

To Spectrograph and SIS Electronics

To Commercial Interface Board for PC
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
GUVI EXPERIMENT

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**
- **GESPAC**
- **GSE**
  - IEEE-488
  - Power Supply
- **Detector Processor Simulation**
- **1773 or RS422**
- **Main Power**
- **Aerospace Boards**
- **ECU**
GSE Configuration -- Stage 2

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

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

Algorithm Development
- High
- Gridding
- Auroral
- Night

Software Development
- Software Specifications Review
- Informal Status Review
- Preliminary Software Requirements Specification
- SRS Rev (a)
- SRS Rev (b)
- Informal Status Review
- Preliminary Design Review
- Critical Design Review
- Final SRS
- Final STR, SDD
- Pre. Software Users Manual
- Pre. Software Users Manual
- Final Software Test Plan
- Functional Configuration Audit
- Test and Integration at SFC
- Delivery of Build 1

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

Software Specifications Review
Informal Status Review
Preliminary Software Requirements Specification
SRS Rev (a)
SRS Rev (b)
Informal Status Review
Preliminary Design Review
Critical Design Review
Final SRS
Final STR, SDD
Pre. Software Users Manual
Pre. Software Users Manual
Final Software Test Plan
Functional Configuration Audit
Test and Integration at SFC
Delivery of Build 1
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:

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 occurrence in time and space.

Existing SSUSI displays already display H Lyman alpha data
• a new module to determine the geocoronal signal and subtract it would be required
• level of effort is small (about 3wm including testing and documentation)
## GUVI GDAS Schedule

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<td>Aurora</td>
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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
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
DPU Interface Simulator

Buffer Electronics per ICD

A/D Converter

PROM

80C186 uProc

Parallel Port Interface Logic

Interface ACTEL Gate Array

RAM

To Sensor Under Test

To Commercial Interface Board for PC
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 UTM/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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<tr>
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<th>FY98 (S/C I/T)</th>
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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

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<th>Prelim</th>
<th>Pre-env</th>
<th>Post-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
What We Have Measured So Far

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

[Image: LYα spectrum with exaggerated scale]
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°, -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.
Line of Sight on the Celestial Sphere

- inclination of the orbit plane 98.3°
- north pole
- angle to 520km tangent point 16.88°
- angle to 200km tangent point 24.15°
- celestial equator
- earth
- orbit
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

200km tangent altitude

GUVI field-of-view

Earth
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
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

normal to orbit plane is at RA=10.5hrs dec=-8.25°

summer solstice 7:30pm orbit

summer solstice 4:30pm orbit

winter solstice 4:30pm orbit

spring equinox 4:30pm orbit

RA=10.5hrs dec=-8.25°
### Limiting Spectral Magnitude (V)

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*for 10% counting statistics in 10nm bin in 15nm (from R.E. Danlels)*
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see CDR Action Item 01a, C/C Plan, TEMP and OPS Plan for more