FOS Geomagnetic Image Motion Problem

Flight Readiness Review

16 December 1992
Outline of FRR

- Summary of the Problem (V. Balzano)
- SOGS Changes (D. Chance)
- SOGS Testing (D. Chance)
- CTA Testing (R. Schneider)
- PASS Software Changes (T. Adams)
- FOS GIMP Test and Analysis (J. Fitch)
What is GIMP?

GIMP is the cyclical drift of the FOS image due to inadequate magnetic shielding
- ~2 cycles/orbit in both the X (dispersion) and Y directions
- Amplitude is ±0.6 diodes (±0.2") on the A side, ±0.15 diodes on the B side.
- Maximum drift rate ~0.1 diode/min on the A side

Why do we need to correct for GIMP?

- GIMP degrades spectral resolution in uncorrected observations
- GIMP reduces photometric accuracy
  - Image motion in Y can result in loss of signal at diode array
- GIMP make spectropolarimetry on the A side impossible
  - Small flux variations between two polarized spectra produce a false polarization signal
- GIMP reduces target acquisition accuracy
  - Binary search TAs can fail due to target motion during search
SO...

FOS x and y deflections are time dependent because the telescope is moving through the Earth's magnetic field

THEREFORE...

We need to add a time dependent term to each FOS deflection

Data show that x and y offsets should be updated about every 40 seconds
Summary of Implementation

- Deflection pattern characteristics are uplinked from the ground
- Actual x and y deflections are controlled by the FOS firmware
- Firmware patch was developed by R. Hier to add an offset to every deflection
- Patch must be reloaded after every microprocessor reset
- SOGS knows:
  - the basic telescope pointing
  - the time of the FOS exposure
  - the detector being used

This information is given to PASS through new data block, FOSGIMP
PASS knows:
  the telescope position
  the Earth's magnetic field

PASS calculates:
  time dependent x and y deflection offsets
  third order polynomial fit for maximum of 30 minute duration

Polynomial coefficients given to NSSC-1 through new table, YFGIMPCB

NSSC-1 calculates:
  x and y deflection offsets every 30 seconds

Deflection offsets given to FOS firmware through two "new" commands,
  YX_DGIMP and YY_DGIMP

FOS firmware adds offsets to every deflection
Ground Elements Involved:

- PDB
- Trans
- SCS
- IM
- 10.2 reconfigurations
- PASS
- IMTOOL
- PODPS

Onboard Elements Involved:

- NSSC-1 flight software
- FOS firmware
SOGS Changes

PEP
GIMP correction is not user selectable

Transformation (OPRs 23288, 23521)
• Determine if GIMP correction should be turned on
  (normally, it will be on for all modes except ACQ/PEAK)

<table>
<thead>
<tr>
<th>mode</th>
<th>GIMP correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCUM</td>
<td>ON</td>
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<tr>
<td>IMAGE</td>
<td>ON</td>
</tr>
<tr>
<td>RAPID</td>
<td>ON</td>
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<tr>
<td>PERIOD</td>
<td>ON</td>
</tr>
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<td>ACQ</td>
<td>ON</td>
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<td>ON</td>
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<tr>
<td>ACQ/BIN</td>
<td>ON</td>
</tr>
<tr>
<td>ACQ/PEAK</td>
<td>OFF</td>
</tr>
</tbody>
</table>

• Increase alignment time to accommodate GIMP correction

• Do not allow slews during FOS internals

• Do not allow sync start and GIMP correction for the same exposure
Commanding (OPRs 22396, 22726, 23070)

Upward transitions
- Hold --> Low Voltage
  - Load RTS (PYGIMP) to patch FOS software for GIMP correction "YKEY commands"

- Low Voltage --> Operate
  - Load table to disable sending of GIMP corrections (YFGMPCRE)
  - Load table to disable GIMP function (YFGMPFCE)
  - Load table to set GIMP status bit in SHP to indicate GIMP correction is OFF (YFGMPSTA)
  - Issue group PY_DGIMP to zero out GIMP offsets
  - Activate RTS (PYGIMP) to load patch to FOS firmware
Excerpts from the 93004 SMS:

```
SMS00GF :TEXT,TIME=(ORB,14732,EASCNCR,01H03M46.000S);
BEGINTEXT;
   RECON- FOS BLUE Hold To Low Voltage
ENDTEXT
;SMSTIME=1993.006:07:16:37.000

SMS00GG :RTS,PYMPUDL,RTSID(YCEAU2XL),LOADBY=(ORB,14732,EASCNCR,01H03M46.000S);
;SMSTIME=1993.006:07:16:37.000

SMS00GH :RTS,PYSEPO,RTSID(YSEPO2XL),LOADBY=(ORB,14732,EASCNCR,01H03M48.000S);
;SMSTIME=1993.006:07:16:39.000

SMS00GI :RTS,PYDFNP,INDEX('YTDF'N),RTSID(YTDF2XL),LOADBY=(ORB,14732,EASCNCR,01H03M50.000S);
;SMSTIME=1993.006:07:16:41.000

SMS00GJ :RTS,PYTO_HLD,INDEX('YOFPP'N),RTSID(YOFPP2XL),LOADBY=(ORB,14732,EASCNCR,01H03M52.000S);
;SMSTIME=1993.006:07:16:43.000

SMS00GK :RTS,PYGIMP,RTSID(YGIMP2XL),LOADBY=(ORB,14732,EASCNCR,01H03M54.000S);
;SMSTIME=1993.006:07:16:45.000

SMS00GL :RTS,PYCLON,RIU2 (B),RTSID(YCLON2XM),LOADBY=(ORB,14732,EASCNCR,01H03M56.000S)

```
SMS00IV :TEXT, TIME=(ORB, 14732, EASCNCR, 01H13M31.000S);
BEGINTEXT;
RECON- FOS BLUE Low Voltage To High Voltage
ENDTEXT
;SMSTYPE=1993.006:07:26:22.000
SMS00KU :GROUP, PYHV_22, TIME=(ORB, 14732, EASCNCR, 01H17M58.000S) ;
;SMSTYPE=1993.006:07:30:49.000

SMS00KY :TABLE, YFGMPCRE, SENDCMDS(NO), TIME=(ORB, 14732, EASCNCR
, 01H19M51.000S)
;SMSTYPE=1993.006:07:32:42.000
SMS00KZ :TABLE, YFGMPFCE, GIMPFUNC(DISABLE), TIME=(ORB, 14732, EASCNCR;
, 01H19M52.000S)
;SMSTYPE=1993.006:07:32:43.000
SMS00L0 :TABLE, YFGMPSTA, STATUS(DISABLE), TIME=(ORB, 14732, EASCNCR
, 01H19M53.000S)
;SMSTYPE=1993.006:07:32:44.000
SMS00L1 :GROUP, PY_DGIMP, X_DGIMP(0), Y_DGIMP(0), TIME=(ORB, 14732
, EASCNCR, 01H19M54.000S)
;SMSTYPE=1993.006:07:32:45.000
SMS00L2 :RTSCTRL, FUNC(ACT), RTSID(YGIMP2XL), TIME=(ORB, 14732
, EASCNCR, 01H19M56.000S)
;SMSTYPE=1993.006:07:32:47.000
Science Commanding

If GIMP correction is to be turned on:

- Load table to set GIMP status bit in SHP to indicate GIMP correction is on (YFGMPSTA)

- Turn off de-gaussing

- Load table to enable GIMP correction (YFGMPCRE)

- Issue FOSGIMP data block
  A new FOSGIMP data block will be issued every 29 minutes during an exposure

- At the end of the exposure, disable GIMP function and corrections (YFGMPFCE and YFGMPCRE)

If GIMP correction is to be turned off:

- Set status bit to indicate GIMP correction is turned off (YFGMPSTA)

- Zero out GIMP offsets (PY_DGIMP)
## FOS GIMP Data Block

(label) FOSGIMP, OPMODE(mnemonic), ORIENT(decimal, decimal, decimal)

[., TICK(integer)]

[., COMPDUR(integer)]

[., ENABLE]

, TIME = absolute time [:]

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<tr>
<th>R</th>
<th>KEYWORD</th>
<th>DESCRIPTION</th>
<th>TYPE</th>
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<th>RESOLUTION</th>
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<tr>
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<td>OPMODE</td>
<td>Data acquisition mnemonic mode</td>
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<td>HST attitude</td>
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<td></td>
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<td>decimal</td>
<td>degrees</td>
<td>0-360</td>
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<td>10⁷</td>
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<td>TICK</td>
<td>First GIMP tick for FOS use</td>
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<td></td>
<td>COMPDUR</td>
<td>Duration range of computation</td>
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<td>0-1800</td>
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<td></td>
<td></td>
<td>(default=1800)</td>
<td></td>
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<tr>
<td></td>
<td>ENABLE</td>
<td>Enable GIMP computation in NSSC1</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>*</td>
<td>TIME</td>
<td>Reference time for table load and computation start</td>
<td>absolute time</td>
<td>UTC</td>
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<td>n/a</td>
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18H02001  :TEXT, TIME=(ORB,14738,EASCNCR,01H27M50.000S);
BEGINTEXT;
START PROP=04495, PROG=18H, OBSID=02, ALIGN=01, EXP=01 ;;
WAVE , POS/BL, RAPID, 2880.00S ;;
A0_3, A4_3, G270H, G130H, , CW1 ;;
Begin Observation
ENDTEXT
;SMSTIME=1993.006:17:18:33.000
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.
.

18H02008  :TABLE, YFGMPSTA, STATUS(ENABLE), TIME=(ORB,14738,EASCNCR ,
01H30M54.000S)
;SMSTIME=1993.006:17:21:37.000
;BEGINNING A&V COMMAND BLOCK YSPTNNS
;BEGINNING A&V COMMAND BLOCK YSDEFL
18H02009  :GROUP, PXDEFLEC, XOFFSET(0), X_BASE(BSCG270H), X_PITCH(1584);
,YOFFSET(0), Y_BASE(BSCG270H), Y_PITCH(1846), Y_RANGE(0) ;;
,TIME=(ORB,14738,EASCNCR,01H30M55.000S)
;SMSTIME=1993.006:17:21:38.000
;BEGINNING A&V COMMAND BLOCK YSDEFP
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<td>18H0200W</td>
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<td>SMSTIME=1993.006:17:23:45.000</td>
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<td>18H0200X</td>
<td>GROUP, PYEFILL, TIME=(ORB, 14738, EASCNCR, 01H33M10.000S)</td>
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<td>SMSTIME=1993.006:17:23:53.000</td>
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<td>18H0200Y</td>
<td>GROUP, PYIFUP, TIME=(ORB, 14738, EASCNCR, 01H33M11.000S)</td>
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<tr>
<td></td>
<td>SMSTIME=1993.006:17:23:54.000</td>
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<td>18H0200Z</td>
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<td>SMSTIME=1993.006:17:23:55.000</td>
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18H02010 :FOSGIMP, COMPDUR(1230), ENABLE, OPMODE(BSCALE)
, ORIENT(1.6611383333333E+02, 3.820875E+01
, 2.69884212179316E+02), TIME=(ORB, 14738, EASCNCR
, 02H01M21.000S)
; SMSTIME=1993.006:17:52:04.000

18H02011 :RTSCTRL, FUNC(ACI), RTSID(YCLOF2XM), TIME=(ORB, 14738
, EASCNCR, 02H21M12.000S)
; SMSTIME=1993.006:18:11:55.000

18H02012 :RTSCTRL, FUNC(ACI), RTSID(YEND2XM), TIME=(ORB, 14738
, EASCNCR, 02H21M25.000S)
; SMSTIME=1993.006:18:12:08.000

18H02013 :RTSCTRL, FUNC(ACI), RTSID(YEND2XM), TIME=(ORB, 14738
, EASCNCR, 02H21M26.000S)
; SMSTIME=1993.006:18:12:09.000

18H02014 :GROUP, PYIFDOWN, TIME=(ORB, 14738, EASCNCR, 02H21M27.000S)
; SMSTIME=1993.006:18:12:10.000

18H02015 :GROUP, PYIPEMP, TIME=(ORB, 14738, EASCNCR, 02H21M28.000S)
; SMSTIME=1993.006:18:12:11.000

18H02016 :GROUP, PYIFUP, TIME=(ORB, 14738, EASCNCR, 02H21M31.000S)
; SMSTIME=1993.006:18:12:14.000

18H02017 :GROUP, FYSD_EN, IMP_TYPE(AUTO), TIME=(ORB, 14738, EASCNCR
, 02H21M32.000S)
; SMSTIME=1993.006:18:12:15.000
18H02018: TABLE, YFGMPCRE, SENDCMDS(NO), TIME=(ORB, 14738, EASCNCR, 02H21M35.000S)
; SMSTime=1993.006:18:12:18.000

18H02019: TABLE, YFGMPFCE, GIMPFUNC(DISABLE), TIME=(ORB, 14738, EASCNCR, 02H21M36.000S)
; SMSTime=1993.006:18:12:19.000
Downward transitions

- Operate --> Low Voltage
  - Load table to disable sending of GIMP corrections (YFGMPCRE)
  - Load table to disable GIMP function (YFGMPFCE)
  - Load table to set GIMP status bit in SHP to indicate GIMP correction is OFF (YFGMPSTA)

- Low Voltage --> Hold
  - Erase/inhibit PYGIMP RTS

Safing recovery

- Halt and inhibit, then enable unique sequence 3

- No other management of unique sequence 3 is done by the commanding
SMS00MN: TEXT, TIME=(ORB, 14738, EASCNCR, 07H07M27.000S);
BEGINTEXT;
RECON- POS BLUE High Voltage To Low Voltage
ENDTEXT

;SMSTIME=1993.006:22:58:10.000
SMS00MO: TABLE, YFGMPCRE, SENDCMDS (NO), TIME=(ORB, 14738, EASCNCR,
07H07M27.000S)
;SMSTIME=1993.006:22:58:11.000
SMS00MP: TABLE, YFGMPFCE, GIMPFUNC (DISABLE), TIME=(ORB, 14738, EASCNCR,
07H07M28.000S)
;SMSTIME=1993.006:22:58:12.000
SMS00MQ: TABLE, YFGMPSRA, STATUS (DISABLE), TIME=(ORB, 14738, EASCNCR,
07H07M29.000S)
;SMSTIME=1993.006:22:58:12.000
BEGINNING A&V COMMAND BLOCK YSHVSET
RECON- POS BLUE Low Voltage To Hold

;SMSTIME=1993.006:22:59:10.000

;SMSTIME=1993.006:23:04:11.000

;SMSTIME=1993.006:23:04:13.000

;SMSTIME=1993.006:23:04:15.000
**PDB Changes** (OPRs 21592, 22813)

**CMDS** - new commands *YX_DGIMP* and *YY_DGIMP*
- used by flight software and commanding to send GIMP corrections to FOS

**TFPF, PTLD, TIDF** - new tables:
- *YFGIMPCB* - used by PASS to load GIMP coefficients
- *YFGMPFCE* - used to enable/disable the GIMP function in the housekeeping AP
- *YFGMPCRE* - used to enable/disable the GIMP corrections
- *YFGMPSTA* - used to load a status bit in the SHP indicating GIMP correction is turned ON/OFF

**PLCP** - new groups:
- *PY_DGIMP* - used to issue the *YX_DGIMP* and *YY_DGIMP* commands
- *PYGIMP* - used to send the *YKEY* commands to patch FOS software

**SICF** - new scale factors used by PASS to scale the GIMP coefficients
PDB Changes (continued)

SHPF - new GIMP error flag (YFGIMP) and GIMP enable flag (YFGIMPEN)

SOIF - new index number for unique sequence #3

SCHF - PASS updated the spacecraft characteristics file with values needed for the GIMP calculation

SCS (OPR 23183)

PODPS/IMTOOL (OPRs 23758, 23112)

New FOS keywords YFGIMP and YFGIMPEN

SCIOSDB (OPRs 22514, 23071)

- Added the definition of FOSGIMP datablock
- Increased the reconfiguration times
Commanding Testing

- Bit validation was done on the two new PLCP groups PYGIMP and PY_DGIMP.
- The FOS commanding instructions were re-certified.
- The GIMP corrections derived from the GIMP coefficients in the PASS products were checked against the corrections independently arrived at by the FOS team.
- Code 512 reviewed the test SMS.
Example PASS products \((\text{CTREPORT.RPT})\):

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<tr>
<th>Time</th>
<th>Value</th>
<th>Description</th>
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</thead>
<tbody>
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<td>13N01123</td>
<td>FOSGIMP, COMPDUR(1800), ENABLE, OPMODE(ASCAL),</td>
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<td>0.02123</td>
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<td>MMLWDSSW 020000A</td>
<td>92:273 15:44:56 1284945 S1203204** N ATP NS TABLE</td>
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<table>
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Example PASS products (CTREPORT.RPT) (continued):

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</tbody>
</table>

MTL

Dono Taylor
0620 - 2008-2015-04-15
Pass products
One week
Deriving GIMP corrections from the PASS products

\[ \begin{align*}
X\text{-gimp} & = A*\text{TICK}^3*2^{-24} + B*\text{TICK}^2*2^{-16} + C*\text{TICK}^2*2^{-12} + D*2^{-8} \\
Y\text{-gimp} & = Z*\text{TICK}^3*2^{-24} + Y*\text{TICK}^2*2^{-16} + X*\text{TICK}^2*2^{-12} + W*2^{-8}
\end{align*} \]

where TICK is GIMP ticks measured in integer multiples of 15sec. TICK = 0 occurs at the time of the YFGIMPCB table load. The coefficients A, B, C, D, Z, Y, X, and W come from the YFGIMPCB table load and appear in the table in that order.

In the case of the first FOSGIMP datablock listed above:

\[ \begin{align*}
A & = \text{003FF95 hex} = -107 \text{ dec} \\
B & = \text{00001C2 hex} = 458 \text{ dec} \\
C & = \text{003F3D8 hex} = -3112 \text{ dec} \\
D & = \text{000077F hex} = 1919 \text{ dec} \\
Z & = \text{003F2FE hex} = -3330 \text{ dec} \\
Y & = \text{00008F5 hex} = 2993 \text{ dec} \\
X & = \text{003EF60 hex} = -4256 \text{ dec} \\
W & = \text{003FDA3 hex} = -605 \text{ dec}
\end{align*} \]

\[ \begin{align*}
\text{If } N_{\text{hex}} > 2000000_{\text{hex}} \\
\Rightarrow N_{\text{dec}} &= -400000_{\text{hex}} + N_{\text{hex}} \\
&= -262144 + \text{dec}(N_{\text{hex}})
\end{align*} \]
GIMP Timeline

1992
- SMS 349
- Begin using new instructions

1993
- 004
- GIMP Test 04495
- 011
- 018
- 025
- 032
- Begin normal use of GIMP correction
- 039
FOS GIMP Test and Analysis

- FOS GIMP Test schedule;
  - Blue side 93.006:07 - 93.006:24
  - Red side 93.007:17 - 93.007:23

- Test Description for proposal 4495
  - Designed to verify all aspects of GIMP correction Software for FOS
    - Commanding
      - FOS Microprocessor reconfiguration
      - GIMP correction flags and coefficients to PASS
    - PASS
      - Magnetic field modeling
      - Commanding and parameters to FSW
    - NSSCI
      - Proper FSW expansion of polynomial
      - Proper timing of serial magnitude commanding to SI
      - No interference with other FOS FSW
      - Proper cleanup
      - Proper telemetry and data logging
    - FOS
      - Proper microprocessor response to commanding
      - Proper correction of data
    - PODOPS
      - Proper handling of SHP data flags
FOS GIMP Test and Analysis

- Test Description for proposal 4495 (continued)
- Each side of the FOS consistist of the following exposures

1: 48 minute rapid readout calibration lamp observation through the G270H grating. Demonstrates GIMP correction which requires two FSW table loads due to length of observation.

2: 48 minute rapid readout calibration lamp observation through the G270H grating. Demonstrates consecutive observations which can occur using the same Polynomials. May require greater than two table loads.

3: 32, 32 second Taled observations (Image mode) spaced approximately 4 minutes apart. Demonstrates mode independance of correction, as well as supporting closely spaced exposures. Provides Y measurement of GIMP correction.

4: 1 32 second Image mode observation with GIMP correction disabled. Demonstrates ability to properly interleave corrected and uncorrected exposures.

5: 1 15 minute Rapid mode calibration lamp measurement through the G270H grating. Demonstrates repeatability of measurement as well as reenabling of GIMP.

6: 1 15 minute Rapid mode calibration lamp measurement through the G270H grating. This shows continuity with a single table load.
FOS GIMP Test and Analysis

- Test Analysis
1. Monitor Microprocessor reconfiguration which includes the YDATA commands to the FOS microprocessor. Y536-Y541 F/W Stat 1 - 6. Should read back ASCII "OK" (79,75 Dec) after proper thread implementation in FOS microprocessor.

2. Monitor flags YGIMPFE (GIMP function enable) and YGIMPCE (GIMP commanding enable). Should read 'Disable' and 'Don't Send' on initial activation of AP.

3. Monitor YGIMPERF flag throughout. Should always read 'Ok'.

4. Monitor YGIMPITK for resetting corresponding to new table loads.

5. Monitor YGIMPX and YGIMPyC for correspondence from predicted values.

6. Check SHP for GIMP Enabled flag (word 175 bit 15 should be 1 for enabled, 0 for disabled.)

7. Check SHP for GIMP Error flag (word 175 bit 16 should be zero for no error, 1 for error.)

8. Analyze Science data to show total movement in X becomes approximately 0.1 Diodes, total movement in Y approximately 8-9 YBase units.

9. Analyze Science data to show absolute image position between sets dominated by FGWH non-repeatability. (No positional hysteresis greater than 0.1 diodes or 8-10 Ybase units.)
FOS GIMP Test and Analysis - YGIMPMON PORTS Page

<table>
<thead>
<tr>
<th>YGIMPMON</th>
<th>F/W Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOS GIMP Correction</td>
<td>YFWSTAT1 0 X^XS</td>
</tr>
<tr>
<td>YGIMPCE Don't Send</td>
<td>YFWSTAT2 0 X^XS</td>
</tr>
<tr>
<td>YGIMPFE Disable</td>
<td>YFWSTAT3 0 X^XS</td>
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<td>YGIMPERROk</td>
<td>YFWSTAT4 0 X^XS</td>
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<td>YFWSTAT5 0 X^XS</td>
</tr>
<tr>
<td></td>
<td>YFWSTAT6 0 X^XS</td>
</tr>
</tbody>
</table>

![Graph showing YGIMPXC, YGIMPYC, YGIMPTIK values over time]