Gas Chromatograph Mass Spectrometer (GCMS)

GCMS FS Flight Operations User’s Manual

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1.0 Scope

This document contains information specific to the GCMS FS operations from launch through Probe separation from the Orbiter.

2.0 Overview of Flight Operations

The nominal Probe operations concept calls for instrument checkouts every six months during the Cruise phase (ref. EID-A sec. 5.2). The checkouts are of two types, Cruise Checkout Scenario 1 (a.k.a. Flight Checkout 1 or CO1), and Cruise Checkout Scenario 2 (a.k.a. Flight Checkout 2 or CO2). Instrument turnon sequence and power allocation for these checkouts is shown in EID-A Table 2.3.1c.

The last checkout before separation of the Probe from the Orbiter is the Depassivation sequence, which for the GCMS consists of two parts. The first turnon is for the Probe battery depassivation, the second is intended to configure the GCMS valves for Entry.

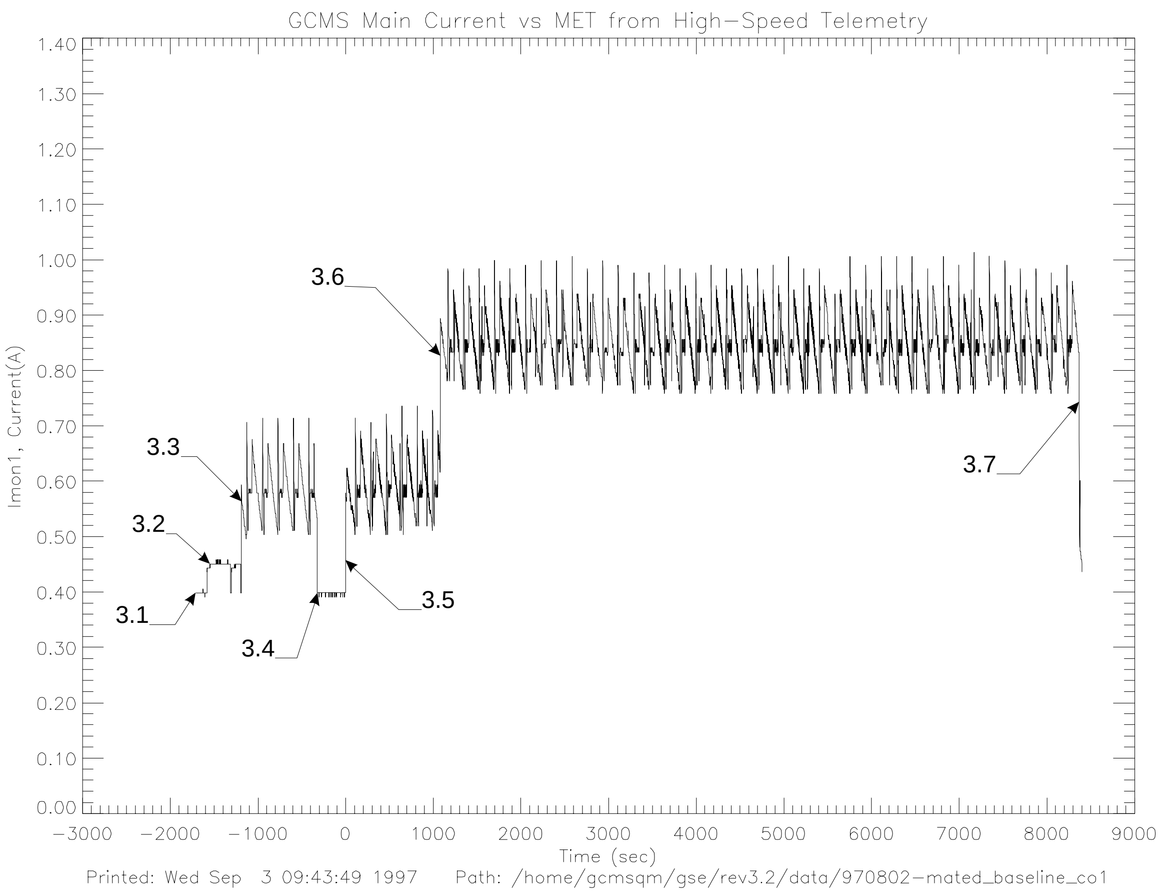
There is no real-time commanding or telemetry during the flight checkouts. Command sequences are uploaded to the Cassini Orbiter Command and Data Subsystem (CDS) before the start of the checkout, and are then sent to the Probe at the specified times. The telemetry data is stored on the Orbiter Solid State Recorder, then transmitted to Earth. For at least one of the planned checkouts (Launch + 6 months) only data from selected time periods will be returned.

3.0 Cruise Checkout Scenario 1

For Cruise Checkout Scenario 1 (CO1), the GCMS operates according to the stored Instrument Command Chains (ICCs) in PROM (see GCMS FS User's Manual, Tables 6.3 and 6.4). Originally, there were no telecommands required from the Probe during this checkout. Telecommands were later added to disable the microvalve operations after one close/open cycle. Since an EEPROM patch is now in place to prevent all microvalve operations, the disable commands are not needed. The telecommands are still sent, as redundancy in case of EEPROM failure (and to avoid modifying the configured checkout sequence).

The timeline of GCMS operations during a nominal CO1 is evident in the plot of instrument current shown in Figure 3.0. The major activities are described below. To interpret the current plot from GCMS High Speed Telemetry data, it is necessary to be familiar with the "marching commutator" scheme. This means that each analog to digital converter channel is "marched" across the mass scan, so that over time each channel is sampled at each mass interval. For example, during unity sweeps if the input current monitor is sampled in mass interval 25 it represents the current draw at AMU 25. On the next scan the current monitor will be sampled at mass interval 24, representing the current draw at AMU 24. At 5.008 msec per mass interval, each scan lasts for 936.5 msec. To cover the 187 mass intervals in a scan thus takes 187 * 936.5 msec, or about 175 seconds. This gives the current waveform seen in the Imon1 Current plots. Because the sampling marches "backwards" in the scan, the current profile is the opposite of what is seen in the stripchart recording of a single scan. The "marching" does not occur during fractional mass scans.

Figure 3.0 GCMS Input Current in Flight Checkout 1



3.1 Initialization

Following instrument poweron, the flight computer (FC) first does checks of the SRAM and PROM memories by calculating checksums and comparing them to the checksum stored in PROM. If the checksums should fail, the FC writes the failure indication to the Status Word, then waits until the Probe has read out the Status Word before continuing. The FC then looks at the Descent Data Broadcast (DDB) from the Probe to determine the Mission Phase. It waits until it has received 10 DDBs (one every 2 seconds, so a 20 second wait), then examines the EEPROM. If the EEPROM passes its checksum, the contents of the EEPROM are applied to SRAM. If not, a Status Word error bit is set and the EEPROM is not used. If the mission phase is Flight Checkout (assumed in this document) then the FC proceeds with the sensor pressure test.

3.2 Pressure Test

In order to make sure the pressure test is valid, the FC commands all valves open before starting the test. Since the valve commands are disabled by an EEPROM patch, the opens do not actually occur, but the FC still performs the valve opening sequence. Once the valves are "opened", the FC examines the reading of the ACP line pressure transducers. If either transducer reads high (present high limit 1.0 V, set in PROM, see GCMS Post-Launch Contingency Commands, Scenario 1) the pressure test fails and the open valve BA test is not performed. If the test passes, the thermistor pressure test is performed. If the thermistor reads above the pass threshold, the test passes (present high limit 2.0 V, set in PROM, see GCMS Post-Launch Contingency Commands, Scenario 2). If the thermistor pressure test fails, the open valve BA test is not performed. If it passes, the FC proceeds to perform the BA pressure test.

For the BA test, the filament is turned on at the lowest emission level. The FC monitors the BA collector current reading for one minute. If during this time the reading drops below 2.5 V, the BA test fails and the filament is turned off. If the reading remains above 2.5 V, the pressure test passes. The FC then increases the BA emission by one DAC step every 5 seconds, continuing to monitor the collector reading. If at any time the reading drops below 2.5 V, the BA filament is turned off. If the reading remains above 2.5 V, the BA filament is left on while the FC commands all valves closed. Again, the valve operations are disabled but the FC still attempts to perform the closes. Once all the valves have been "closed", the BA filament is turned off and the pressure test is repeated. The results of this second test do not affect the status of the pressure test pass/fail determination which was made based on the first, "open valve" test. It is done only for diagnostic purposes. During the second pressure test, the BA filament will be turned on regardless of the results of the ACP and thermistor readings. The standard stepping of BA emission is performed, then the BA filament is turned off.

The initialization and pressure test sequences together require about 8 min. 45 sec. to complete. Since the Probe time is about 20 seconds when the GCMS is turned on, the Probe time is about 9:05 when the instrument enters Run mode. If the pressure test fails, the instrument will not enter Run mode.

3.3 Run Mode, Pre-T0

As the instrument enters Run mode at the conclusion of the pressure test, the FC first turns on the electron multipliers, then starts the RF sweep. The FC then begins executing the Flight Checkout Pre-T0 ICC. This stored sequence turns on only one filament, for Ion Source 5. For the first minute of Filament 5 on time, the ion pumps are turned off. Then both sets of ion pumps are turned on. Had valve operations not been disabled, all non-rupture valves would be still be closed at this point, since they would have been closed during the BA sequence. The ICC contains commands to open all the valves. Although there is presently a software patch to disable valve operations, it is still necessary to be aware of where the commands occur in the stored sequence. The ICC is always running and can produce unintended valve operations if the patch is overridden, such as in a troubleshooting telecommand sequence.

3.4 Pre-Entry Mode

To simulate the Descent Pre-Entry Mode, the Flight Checkout Pre-T0 ICC contains commands to turn off the filaments and ion pumps at 23:00. Independent of the ICC, at 23:30 the flight software turns off the electron multipliers and the RF sweep to place the instrument in a low power mode. This low power mode lasts until T0.

3.5 Run Mode, Post-T0

In Flight Checkout 1 the pre-T0 time lasts for 29 minutes. (In Flight Checkout 2 the pre-T0 time lasts for 36 minutes.) When the DDB indicates that the time is post-T0, the instrument leaves low power mode, with the FC turning the electron multipliers and RF back on. (It should be noted that if the pressure test failed, the electron multipliers and RF will still be turned on after T0, even though they will not be turned on before T0.)

For the first 18 minutes after T0, the GCMS current is still restricted, so only Filament 1 is turned on. The ion pumps are turned back on after one minute of data with no pumps. At 18 minutes the remaining filaments are turned on.

Most of the commands in the post_T0 ICC are for valve operations, which are now disabled. The only valve operations not disabled are the "open" commands for the injection valves, to verify the Arm plug connection.

At about 29 seconds after T0 the ACP is powered on, and a spurious ACP sync pulse is sometimes produced. Then from 0:02:00 to 0:02:47 the ACP sends eight sync pulses, to verify the interface.

3.6 End of Reduced Power Period

At 18 minutes after T0 the remaining 4 ion source filaments are turned on.

A telecommand sequence is performed from 0:22:53 to 0:23:24, consisting of 30 commands (on each channel) to disable all non-rupture valves. This sequence is now redundant since the EEPROM patch disables valve operations.

Some of the heaters (not the Inlet) are commanded on in the sequence. There is no Protected Power during Cruise, so turning them on only verifies that the ICC command is working.

From 1:08:27 to 1:08:40, the ionization potential for the ACP source is set to 50 V. Note that this ICC command will override any ionization potential telecommands which may be sent.

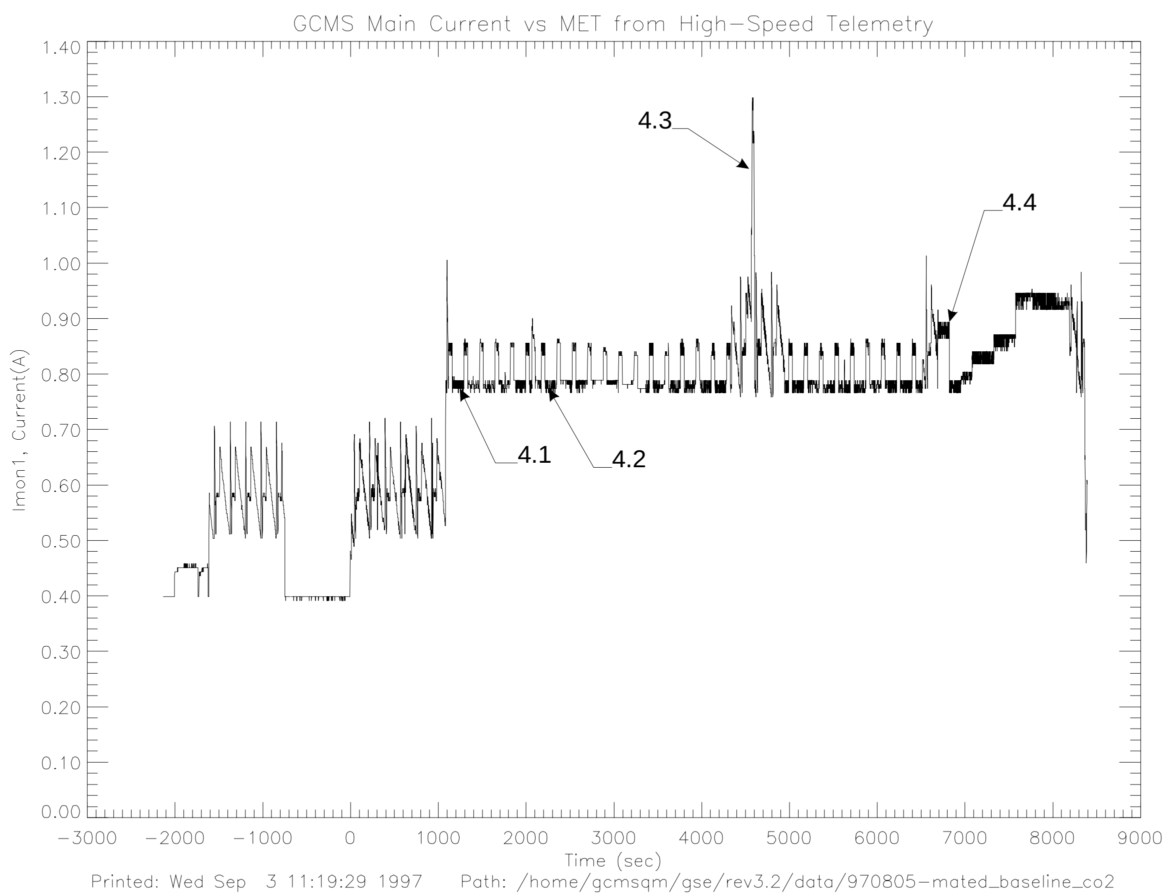
3.7 Deactivate Mode

At the end of the checkout sequence the instrument is placed in Deactivate mode by the DDB mission phase. The original intent of Deactivate was to allow the GCMS valves to be opened. Since valve operations are inhibited, Deactivate mode is optional. (For some contingency sequences which are intended to leave valves closed, Deactivate is specifically not used because an EEPROM or telecommand error could allow Deactivate to open the valves again.)

4.0 Cruise Checkout Scenario 2

Cruise Checkout Scenario 2 (CO2) is the second type of standard flight checkout procedure. It contains many commands to the GCMS to perform counter threshold scans, ion source switching lens scans, place the instrument in a high power mode, and dwell on specified mass ranges for a mass tune check. (See the ATOL command listing in the FS User's Manual.) Until 19 minutes after T0, the GCMS operation is the same as described above for Cruise Checkout Scenario 1. The only difference is that the Pre-T0 time in CO2 is 36 minutes; this is done so that the Probe CDMU A will time out (at 35 minutes) and CDMU B will become valid. This verifies that the instruments can receive commands from either channel.

Figure 4.0 GCMS Input Current in Flight Checkout 2



4.1 Threshold scan

The RF is set to dwell on 28 AMU (except for Totals), and ionization energy switching is disabled. Electron Multiplier 1 is set to about 100 V below nominal, and the counter threshold for Channel 1 is stepped from the lowest usable setting (1) to the highest setting (15). The multiplier voltage is then set to nominal and the threshold scan repeated. The multiplier voltage is set to 75 V above nominal, and the threshold scan done again. The test contains steps for performing a scan of Channel 2 at the nominal multiplier voltage, but since Channel 2 has been disabled in software the scan is not meaningful.

For the Flight Spare, Electron Multiplier 2 was found to be too noisy to be useful. In fact, setting the voltage on the multiplier above 2300 V resulted in an immediate flight computer reboot, presumed to be due to arcing in the multiplier. Therefore, the setting of Electron Multiplier 2, DAC number 18, is nominally zero but is commanded to a low value (40, approximately 500 V) during the flight checkout just to give a reading of the strip current.

If the "pseudo pulse-height distribution" from the threshold scan shows that at the nominal multiplier voltage the counts are lower than desired at the default threshold setting of 4, then the nominal multiplier voltage can be increased. This is done by loading an EEPROM memory patch. Before launch, there was already a patch installed to lower the voltage from the PROM value of 2950 V (DAC setting of 230 decimal) to a value of 2700 V (DAC setting of 211 decimal). The change requires writing the desired DAC setting to memory address FD08 hex.

If the noise level is too high at the default threshold setting of 4, the setting can be changed by loading an EEPROM patch to write the desired setting to memory address FD07 hex. The threshold for channel 1 is the least significant nibble and for channel 2 the most significant nibble. It is easiest to change these values in hexadecimal, e.g. the present value is 44 hex to set both to 4; to set channel 1 to level 6 the value 46 hex would be written.

Note that these EEPROM changes will not take effect until the flight computer is rebooted.

4.2 Ion Source Switching Lens Scans

Each switching lens that is under computer control is stepped through seven voltages, three on each side of the nominal. This is to verify that the optimum lens tuning has not changed. The sequence tests ion sources 1 through 5, with the scans for Ion Source 3 separated by the High Power sequence (in an attempt to keep the peak power within the timeline negotiated with ESA).

Before launch, the lens scans for Ion Source 1 were not completely optimized, but the scans were stable and repeatable so it was decided not to try for the additional 15 to 20 % signal increase which better tuning could have given.

If the lens scans require changes to the voltages, the changes should first be made in the telecommand sequence and verified in a flight checkout before the new voltages are uploaded to EEPROM. The addresses to which the new DAC settings are to be loaded are the same as those used in the telecommand sequence to perform the lens scans.

4.3 High Power Mode

In this part of CO2 the instrument is commanded to draw the maximum amount of current. This is done by setting the RF to dwell on mass 19, turning on the BA filament, and turning on the Inlet and H2 heaters. This is the highest current that can be drawn in the absence of a load on the ion pumps.

4.4 Mass Tuning Check

In order to get better statistics on the location and shape of mass peaks, the instrument is commanded to dwell on specified mass ranges in fractional sweep mode on Ion Source 1. Data analysis programs can then average the sweep data over several minutes. If the mass peaks have an incorrect location or shape, new tuning parameters can be uploaded to EEPROM. As before, it is preferable to test the new parameters in a flight checkout telecommand sequence before loading them to EEPROM. Before launch the EEPROM contained tuning parameter patches; new patches will overwrite the old patches when copied to SRAM. The addresses to patch are:

```
; Bias Addresses                  Present value (hexadecimal)
 AC_Bias_LF_Addr = #FFF3          #FFFD
 AC_Bias_HF_Addr = #FFF4          #FFEC
 DC_Bias_LF_Addr = #FFF5          #0001
 DC_Bias_HF_Addr = #FFF6          #000A
;
; Gain Addresses
 AC_Gain_LF_Addr = #FFF7          #0400
 AC_Gain_HF_Addr = #FFF8          #043E
 DC_Gain_LF_Addr = #FFF9          #03FD
```

DC_Gain_HF_Addr = #FFFA   #0458

Note that: Bias values are 16 bit signed integers, so that 0001 = +1; #FFFD = -3 Gains are divided by #0400 when applied, so that #0400 represents a final gain of 1; #043E/#0400 = 1086/1024 = Gain of 1.06; #03FD/#0400 = 1021/1024 = Gain of 0.997.

If a telecommand sequence is to be developed which tests several different tuning combinations, it is important to remember that the commanded changes will not take effect until the next recalculation of the VAC and VDC values. Ordinarily, the flight software recalculates the VAC and VDC values once every 16 scans. This means that it recalculates about every 15 seconds when in unity sweep mode. When in fractional sweep mode, which is typically used for mass tuning, it recalculates every 16 * 8 = 128 scans, or two minutes. If it is necessary to recalculate more often, the following command can be used:

```
tc cdms g_f_cx_memload_1_a(0,#C2F0,0)
```

This results in the recalculation being done 16 times faster, or about every 8 seconds in fractional sweep mode.

5.0 Depassivation and Coast Valve Configure

The last checkout before Probe separation from the Orbiter consists of two powerons for the GCMS. The first is for the Probe battery Depassivation sequence. The GCMS was not originally powered on during this sequence, but ESA determined that more power was required to properly depassivate the batteries, so the GCMS was added to the sequence. The test consists of 32 minutes in pre-T0, but with mission phase Suspended at a Probe time of 50 seconds. Time resumes at about 4 minutes then increments normally. The suspended time results in an extended BA test time, so the ICC begins executing after the normal start time of 9 minutes Probe time. The only significant effect this has on the operation is that the ion pumps are turned on less than one minute after Filament 5. Since the first few minutes of data have the same time stamp, when the housekeeping data is plotted some points will overlap.

Immediately after the battery depassivation, the GCMS is powered on again in order to close some valves for the Coast phase, so that they would be in the Entry configuration. This sequence was developed before it was decided not to operate the valves; the test was retained in case the decision is later made to close some of the valves during Coast. The command sequence presently will not result in any valve closure, since it does not override the EEPROM software patch which disables valve operation in Flight Checkout.

The Coast Configuration turnon lasts for approximately 19 minutes in pre-T0. Starting at a Probe time of 15 minutes, a total of 119 commands per channel are sent to (redundantly) configure the valves. The telecommands are complete by 17:21.

6.0 Creating telecommand files

Telecommands which are to be sent during Flight must be submitted to ESOC in what is known as the CRID format, as described in the Command Request Interface Document. The command files are first created in ATOL and tested on the breadboard and/or spare instrument. The ATOL sequence files must be located in the /home/gcmsqm/gse/rev3.2/CRID/Sequences directory. (This is nominally a link to the /home/gcmsqm/gse/rev3.2/data/Sequences directory where all ATOL sequences are kept. However, the link can get modified when directories are copied, so it may be necessary to explicitly copy the ATOL files to the ./CRID/Sequences directory.) From the /home/gcmsqm/gse/rev3.2/CRID directory, run the program atol2crid. The parameters for the command are:
atol2crid [sequence filename] [sequence start time in seconds]

The CRID specification says that the start time is referenced to T0, and can be positive or negative. In practice, however, ESOC has generally requested that for the pre-T0 period the commands be referenced to instrument poweron. So far no single CRID file has crossed the T0 boundary. When submitting the CRID to ESOC, it must be clearly stated what time was used as the CRID start time.

The atol2crid program prompts for the checkout type, checkout number, revision, and checkout date. All previous CRID files have been submitted with the V (test) type. Future submissions may use the O (operational) type.

There are other instrument and Probe commands during a checkout, so it is not always possible to have GCMS commands at an arbitrary time. ESOC identifies command conflicts and requests time changes if necessary. If the commands increase the instrument power consumption, care must be taken not to exceed the GCMS allocated current.

6.1 CRID files in the ESOC database

Several CRID files have been submitted to ESOC. Some are actually used in the flight checkouts, while others are for possible contingencies, and still others are now obsolete. The CRID files at ESOC are located on an ftp server. To access the server to upload or download files, ftp to:
ftp1.esoc.esa.de
User: csollazz
Pass: huygens
Change to the /private/csollazz/crid/gcms directory. Be careful when uploading or downloading, as it is possible to delete existing files in the directory. The CRID files are self-documenting to a large extent.

CRID file	Description
HIRGV00101.CR HIRGV00102.CR	Used only for special ESOC test to verify Status Word decoding and telecommand generation
HIRGV00201.CR	FM instrument version of Flight Checkout 2
HIRGV00301.CR	Sequence for Inlet Heater turnoff, used in ground testing
HIRGV00401.CR	Sends GO telecommand, used in ground testing
HIRGV00501.CR HIRGV00502.CR	Intended to configure valves for Coast; to be run during last GCMS poweron before separation. Does not contain memory loads to enable valve operations, so has no effect in present GCMS configuration.
HIRGV00701.CR	FS instrument version of Flight Checkout 2
HIRGV00801.CR	Disables valves after T0 in Flight Checkout 1. With present EEPROM patch to inhibit valves, this sequence is redundant.
HIRGV00901.CR	Was to be used to load EEPROM patch CMP-068 after launch. (Patch was loaded before launch.)
HIRGV01001.CR	Was to be used to verify EEPROM patch CMP-068 after launch
HIRGV01101.CR HIRGV01102.CR	Contingency sequence for post-launch Anomaly 1 (Loads new thermistor pass value.)
HIRGV01201.CR HIRGV01202.CR	Contingency sequence for post-launch Anomaly 2 (Loads new ACP line pressure pass value.)

HIRGV01301.CR HIRGV01302.CR	Contingency sequence for post-launch Anomaly 3 (Closes valves to sensor area.)
HIRGV01401.CR HIRGV01402.CR	Contingency sequence for post-launch Anomaly 4 (Closes valves in sequence to locate leak.)
HIRGV01501.CR	Contingency sequence for post-launch Anomaly 4a (Isolates GC system in case of leak.)
HIRGV01601.CR	Contingency sequence for post-launch Anomaly 4b (Isolates ACP system in case of leak.)
HIRGV01701.CR	Contingency sequence for post-launch Anomaly 4c (Isolates Enrichment Cell system in case of leak.)
HIRGV01801.CR	Contingency sequence for post-launch Anomaly 5 (Opens all valves in case some were closed.)
HIRGV01901.CR	Same as HIRGV01801.CR, resubmitted during "green card" simulation at ESOC.
HPWGV00201.CR	Contains power profile information for Flight Checkout 2