MODULUS – Ptolemy

Ptolemy Mode Description: Module CC – Sample combustion

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CHANGE RECORD

DATE	CHANGE DETAILS	ISSUE
01 September 2013	Document created	1.0
10 September 2013	Added TCs for setting different oven temperatures	1.1
05 November 2013	RF calibration included within script after GRM repair and testing	1.2

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1. Introduction

This document describes the command sequence and operation of the Ptolemy Sample combustion Module. The module heats a sample contained in a high temperature oven with oxygen previously generated by executing module H, supplied from copper oxide within R5. The sample is heated to a maximum temperature of +800ºC. During the combustion volatiles are released into the manifold system and into the expansion volume containing R5. Allowing the evolved gases to contact the copper oxide aids in completely oxidising any partially combusted products.

1.1 Applicable Documents

Ref	Title	Document Number	Issue	Date
AD1	Ptolemy Telecommand and Telemetry Definitions	RO-LPT-RAL-TN-3403	5.1	26 Feb 02
AD2	Ptolemy Operations plan	RO-LPT-OU-PL-3101	4.0	25 Nov 10
AD3	Ptolemy Flight Operations Plan for the First Science Sequence	RO-LPT-OU-PL-3147	1.0	24 Aug 13
AD4	Ptolemy Initialisation Description	RO-LPT-OU-PL-3112	1.0	13 Jul 04

2. Sample combustion Module

This module performs the sequence of commands to heat the sample oven whilst oxygen is present. It is assumed that oxygen has already been generated within the expansion volume by prior execution of module H which terminates with R5 still operating.

2.1 Sequence outline

1. Switch on R5 at full power with a target temperature of+ 850°C so that the module can be tested in standalone mode.
2. The temperature of R5 and AD590. Measure the currents on the 5.2V and 28V voltage rails.
3. Switch on the transfer pipe heater at 20% power (PWM 0-49), target temperature +100°C to prevent the pipe being blocked by ice.
4. Wait 30 seconds whilst monitoring the temperature of the transfer pipe and R5.and the pressure in both manifolds.
5. Evacuate any residual gas within the manifolds.
6. Admit oxygen to manifold 2 by opening V9. Open V13 and switch on the mass spectrometer. Measure the pressure in the manifolds and temperature of the transfer pie and R5. Perform a mass spectrometer RF Calibration.
7. Continue monitoring pressure and temperature whilst allowing time for system to stabilise. Then analyse the oxygen gas for 10 seconds. (6 spectra of WGA7). Switch off the mass spectrometer and close V13.
8. Admit oxygen into manifold1 and the sample oven by opening V2 and V4. End heating of R5 to keep current on 28V rail <900mA. (The fast temperature drop of R5 should not allow oxygen to be resorbed).
9. Heat the sample at full power for 4 minutes with a target temperature of +800°C. Monitor the temperature of the sample oven, transfer pipe and R5. Monitor the pressure in both manifolds.
10. End sample combustion. Switch off ROven and transfer pipe heater. Switch on R5 at full power, target temperature +750°C. R5 will begin to resorb oxygen.
11. Measure temperatures of the R5 and sample oven. Measure the currents on the 5.2V and 28V voltage rails.

The detailed Ptolemy sequence is listed in section 4.

At the end of the sequence Ptolemy returns to standby mode and Valves V2, V4, V9 and V11 are open and R5 is operating at full power with a target temperature of +750°C. Ptolemy will remain in this state until commanded to start the next module (Module I – resorb oxygen) or commanded into Safe mode.

2.2 Resources

Start State – R5 operating at full power, target temperature +850°C
End State – Valves V2, V4, V9 and V11 open, R5 operating at full power, target temperature +750°C

Subsystems operated:
Valves: V2, V4, V7, V9, V11, V13
Heaters: PIPE
Reactors R5, ROven
Mass spec. WGA check (RF Calibration replacement), WGA7

Data Volume:

Aux Science packets	7
Spectrum packets	30
Number of spectra	6

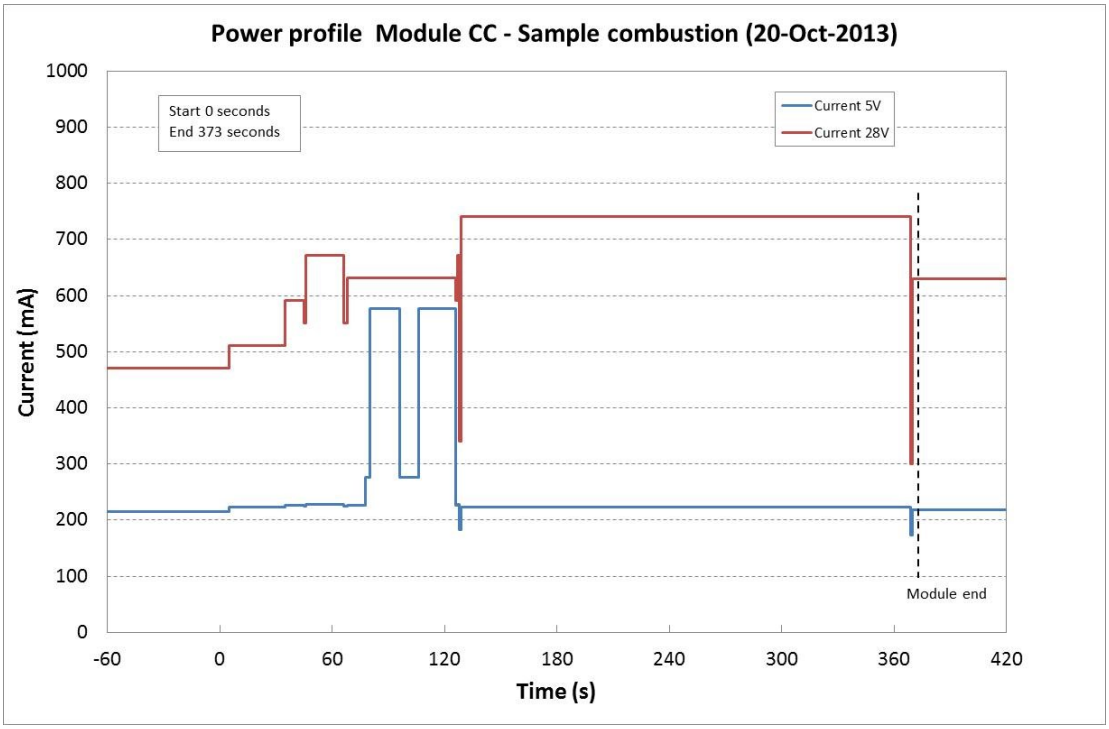
Resources:

Helium used	none
Hydrogen used	none
Oxygen used	none
Reference gas	none
Nano-tip use	0.5 s

Power profile Nominal:	5.2V Supply Rail		28V supply rail	
	Current (mA)	Power (W)	Current (mA)	Power (W)
Average	259	1.35	689	19.28
Maximum	613	3.19	800	22.40

Duration 373 s
Total energy 7683 J

Calculated power profile



2.3 Ptolemy Models

A summary of the use of Module CC – Sample combustion with the various Ptolemy models is given below.

Model	Use	Power Profile (c.f. FM)	Timing (c.f. FM)	Sensors
FM	Limited	-	-	-
QM	Vacuum, Limited	Same, except no transfer pipe heater	Same	Same
CSS	Any time	Different	Same	Pressure sensors and heater different
GRM	Any time	Different	Same	Pressure sensors and heater different

2.3.1 Flight Model (FM)

Module CC – Sample combustion can only be used if the tapping station is docked with a high temperature oven, otherwise oxygen generated by R5 will be evacuated into space, potentially losing all of the oxygen supply.

2.3.2 Qualification Model (QM)

Module CC – Sample combustion can be used on the Ptolemy QM under certain conditions. If executed whilst the QM is in air the mass spectrometer must be disabled. In addition a sample oven or other means of sealing the transfer pipe must be employed to prevent oxygen being depleted during operation.

2.3.3 Chemistry Set Simulator (CSS)

Module CC – Sample combustion can be used on the CSS at any time. The timings should be the same as for the FM. As thermal properties of the heater simulators are different from the FM, the power profile will be different from the FM. The CSS does not simulate gas flow in the manifolds, so the pressure sensors will not give the same results as the FM.

2.3.4 Ground Reference Model (GRM)

Module CC – Sample combustion C can be used on the GRM at any time. The timings should be the same as for the FM. As thermal properties of the heater simulators are different from the FM, the power profile will be different from the FM. The GRM does not simulate gas flow, so the pressure sensors will not give the same results as the FM

3. Operation of the Module CC – Sample combustion

3.1 Load Ptolemy Memory

In order to operate the Prepare helium module, the commands have to be loaded onto Ptolemy EEPROM using the Ptolemy Load Memory TC (AD1). The TCs to upload the Prepare helium module only need to be transmitted once for each Ptolemy instrument, unless a check memory TC indicates that the Ptolemy EEPROM has become corrupted.

Total number of Load memory TCs 14
Number of words 296
Sequence control C780 to C78D
Memory address page 5 offset 7800 to 7A4E

Load memory Module CC– Sample combustion TC1 of 14

1F3C C780 0039 1006 0200 9701 0005 7800
0016 3000 010C 5926 EE00 FF30 0001 28A8
28CE 28D4 28D6 3000 0128 A828 CE28 D428
D630 0001 28A8 28CE 28D4 28D6 3000 467F

Load memory Module CC – Sample combustion TC2 of 14

1F3C C781 0039 1006 0200 9701 0005 782C
0016 0114 7503 8C00 3128 A828 C428 9628
9830 000A 28A8 28C4 2896 2898 3000 0A28
A828 C428 9628 9830 000A 000D 0019 4485

Load memory Module CC – Sample combustion TC3 of 14

1F3C C782 0039 1006 0200 9701 0005 7858
0016 28A8 28C4 2896 2898 3000 0228 A828
C428 9628 9830 0002 28A8 28C4 2896 2898
3000 0228 A828 C428 9628 9830 0002 94F4

Load memory Module CC – Sample combustion TC4 of 14

1F3C C783 0039 1006 0200 9701 0005 7884
0016 28A8 28C4 2896 2898 3000 0200 1830
0001 0003 0007 0015 28A8 28C4 2896 2898
3000 0528 A828 C428 9628 9830 0005 14C1

Load memory Module CC – Sample combustion TC5 of 14

1F3C C784 0039 1006 0200 9701 0005 78B0
0016 28A8 28C4 2896 2898 3000 0528 A828
C428 9628 9830 0005 0002 0006 000C 3000
0200 1100 1945 0328 A828 C428 9628 3810

Load memory Module CC – Sample combustion TC6 of 14

```
1F3C C785 0039 1006 0200 9701 0005 78DC
0016 9830 0002 28A8 28C4 2896 2898 3000
0228 A828 C428 9628 9830 0002 28A8 28C4
2896 2898 3000 0228 A828 C428 9628 13B1
```

Load memory Module CC – Sample combustion TC7 of 14

```
1F3C C786 0039 1006 0200 9701 0005 7908
0016 9830 0002 3000 0282 28A8 28C4 2896
2898 3000 0228 A828 C428 9628 9830 0002
28A8 28C4 2896 2898 3000 0228 A828 1AF4
```

Load memory Module CC – Sample combustion TC8 of 14

```
1F3C C787 0039 1006 0200 9701 0005 7934
0016 C428 9628 9830 0002 28A8 28C4 2896
2898 3000 0212 0705 0006 0144 0018 3000
0100 0300 0730 0001 28A8 28C4 2896 7176
```

Load memory Module CC – Sample combustion TC9 of 14

```
1F3C C788 0039 1006 0200 9701 0005 7960
0016 2898 0C58 3000 010C 6F24 6B00 FF28
BE28 C428 A828 9628 9828 CE30 0014 28BE
28C4 28A8 2896 2898 28CE 3000 1428 D899
```

Load memory Module CC – Sample combustion TC10 of 14

```
1F3C C789 0039 1006 0200 9701 0005 798C
0016 BE28 C428 A828 9628 9828 CE30 0014
28BE 28C4 28A8 2896 2898 28CE 3000 1428
BE28 C428 A828 9628 9828 CE30 0014 990C
```

Load memory Module CC – Sample combustion TC11 of 14

```
1F3C C78A 0039 1006 0200 9701 0005 79B8
0016 28BE 28C4 28A8 2896 2898 28CE 3000
1428 BE28 C428 A828 9628 9828 CE30 0014
28BE 28C4 28A8 2896 2898 28CE 3000 E746
```

Load memory Module CC – Sample combustion TC12 of 14

```
1F3C C78B 0039 1006 0200 9701 0005 79E4
0016 1428 BE28 C428 A828 9628 9828 CE30
0014 28BE 28C4 28A8 2896 2898 28CE 3000
1428 BE28 C428 A828 9628 9828 CE30 3E8A
```

Load memory Module CC – Sample combustion TC13 of 14

```
1F3C C78C 0039 1006 0200 9701 0005 7A10
0016 0014 28BE 28C4 28A8 2896 2898 28CE
3000 140C 6E14 7430 0001 0C59 21E8 00FF
28A8 28CE 28D4 28D6 3000 0128 A828 009E
```

Load memory Module CC – Sample combustion TC14 of 14

```
1F3C C78D 0021 1006 0200 9701 0005 7A3C
000A CE28 D428 D630 0001 28A8 28CE 28D4
28D6 3000 01FF D20F
```

3.2 Execution of Module CC – Sample combustion

The sequence to execute Module CC – Sample combustion in a Standalone mode is as follows:

1. Start with Ptolemy switched on and having transmitted the Ptolemy Initialisation TCs
2. Check Memory Module CC
3. Transmit TC to set Ptolemy into Standby mode
4. Transmit TC to enable the relevant Ptolemy subsystems
5. Transmit TC to define module start address
6. Transmit TC to Begin Sample combustion module
7. Once the Sample combustion module has been completed then transmit TC to set Ptolemy into Safe mode

The sample oven temperature can be defined by loading the oven temperature value at address 0x7968 and 0x796A. If the oven temperature is not defined then it will remain at the previously set value (or +800ºC for a new load of the module).

TC: Load memory CC oven temperature +180 deg C

1F3C F170 0011 1006 0200 9701 0005 7968
0002 6F06 BB00 CFA5

TC: Load memory CC oven temperature +200 deg C

1F3C F171 0011 1006 0200 9701 0005 7968
0002 6F07 9100 CFA7

TC: Load memory CC oven temperature +300 deg C

1F3C F172 0011 1006 0200 9701 0005 7968
0002 6F0B F400 3C19

TC: Load memory CC oven temperature +400 deg C

1F3C F173 0011 1006 0200 9701 0005 7968
0002 6F10 9B00 4A80

TC: Load memory CC oven temperature +600 deg C

1F3C F174 0011 1006 0200 9701 0005 7968
0002 6F1A 6200 1E07

TC: Load memory CP oven temperature +800 deg C

1F3C F175 0011 1006 0200 9701 0005 7968
0002 6F24 6B00 A424

TC: Check Memory Module CC

1F3C F103 0019 1006 0900 9703 0005 7800
0064 0005 78C8 0064 0005 7990 0060 D974

The results of the Memory check TC are returned as a Check memory report within a Housekeeping packet.

Memory Address		Number of Words	Expected Checksum
Page	Offset		
0005	7800	0064	C50B
0005	78C8	0064	E2ED*
0005	7990	0060	1FB7

*Checksums will vary depending upon the defined oven temperature

Defined oven temperature	Hex value	Check sum result Word 2
+180ºC	06BB	32CF
+200ºC	0791	18CE
+300ºC	0BF4	7DC2
+400ºC	109B	12D9
+600ºC	1A62	EBD3
+800ºC	246B	E2ED

TC: Parameter update – define Module CC start address

1F3C F123 000D 10C3 0100 1FFE 0002 0005 7800 16C6

Updates parameter 0x1FFE with two words to define the start address as EEPROM page 5 0x7800

TC: Start Module CC – Sample combustion

1F3C F143 0005 10C1 0800 CDA2

The TCs listed below were used to execute Module CC on the CSS on 20-Oct-2013 having initialised Ptolemy with Initialisation(3).seq (AD4)

```
Check memory      1F3C F103 0019 1006 0900 9703 0005 7800
                  0064 0005 78C8 0064 0005 7990 0060 D974
Start Standby     1F3C C000 000B 10C1 0000 0009 0000 0000
                  CE64
Hazard enable     1F3C C000 000B 10C2 0100 FFFF FBFF 0070
                  3239
Update parameter  1F3C F123 000D 10C3 0100 1FFE 0002 0005
                  7800 16C6
Start Module CC   1F3C F143 0005 10C1 0800 CDA2
Select Safe mode  1F3C F004 0005 10C1 FF00 C48F
```

4. Script Module CC – Sample combustion

Script file name: FSS2 Module CC - Sample combustion (20-Oct-2013)

96 Commands

Time (s)	Command	Comments
2	Time Delay, , , , 1, Reactor, R5, Begin, 850, 0, 255 Time Delay, , , , 1,	Switch on R5 at full power with a target temperature of+ 850°C so that the module can be tested in standalone mode.
5	Loop, , Begin, 3, , Aux Data, tR5, , , , Aux Data, AD590, , , , Aux Data, i5V, , , , Aux Data, i28V, , , , Time Delay, , , , 1, Loop, , End, , ,	The temperature of R5 and AD590. Measure the currents on the 5.2V and 28V voltage rails.
5	Heater (pwm), PIPE, Begin, 100, 0, 49	Switch on the transfer pipe heater at 20% power (PWM 0-49), target temperature +100°C to prevent the pipe being blocked by ice.
35	Loop, , Begin, 3, , Aux Data, tR5, , , , Aux Data, tPIPE, , , , Aux Data, pG4, , , , Aux Data, pG5, , , , Time Delay, , , , 10, Loop, , End, , ,	Wait 30 seconds whilst monitoring the temperature of the transfer pipe and R5.and the pressure in both manifolds.
	Valve, V7, Open, , , Valve, V13, Open, , , Loop, , Begin, 5, , Aux Data, tR5, , , , Aux Data, tPIPE, , , , Aux Data, pG4, , , , Aux Data, pG5, , , , Time Delay, , , , 2, Loop, , End, , , Valve, V13, Close, , , Time Delay, , , , 1, Valve, V2, Open, , , Valve, V4, Open, , , Valve, V11, Open, , , Loop, , Begin, 4, , Aux Data, tR5, , , , Aux Data, tPIPE, , , , Aux Data, pG4, , , , Aux Data, pG5, , , ,	Duration 33 seconds. Evacuate any residual gas within the manifolds.

68	Time Delay, , , , 5, Loop, , End, , , Valve, V2, Close, , , Valve, V4, Close, , , Valve, V7, Close, , ,	
98	Time Delay, , , , 2, Valve, V9, Open, , , Valve, V13, Open, , , Set MS, IT 3, On, , , Loop, , Begin, 5, , Aux Data, tR5, , , , Aux Data, tPIPE, , , , Aux Data, pG4, , , , Aux Data, pG5, , , , Time Delay, , , , 2, Loop, , End, , , Time Delay, , , , 2, Calibrations, RF Cal, , , ,	Duration 30 seconds Admit oxygen to manifold 2 by opening V9. Open V13 and switch on the mass spectrometer. Measure the pressure in the manifolds and temperature of the transfer pie and R5. Perform a mass spectrometer RF calibration.
129	Loop, , Begin, 5, , Aux Data, tR5, , , , Aux Data, tPIPE, , , , Aux Data, pG4, , , , Aux Data, pG5, , , , Time Delay, , , , 2, Loop, , End, , , MS Acquire, IT 5, , 7, 6, 1 Set MS, , Off, , , Valve, V13, Close, , , Time Delay, , , , 1,	Analyse oxygen produced from R5 Duration 31 seconds. Continue monitoring pressure and temperature whilst allowing time for system to stabilise. Then analyse the oxygen gas for 12 seconds. (6 spectra of WGA7). Switch off the mass spectrometer and close V13.
131	Valve, V2, Open, , , Valve, V4, Open, , , Time Delay, , , , 1, Aux Data, tR5, , , , Aux Data, tPIPE, , , , Aux Data, pG4, , , , Aux Data, pG5, , , , Reactor, R5, End, , , Time Delay, , , , 1,	Admit oxygen into manifold1 and the sample oven by opening V2 and V4. End heating of R5 to keep current on 28V rail <900mA. (The fast temperature drop of R5 should not allow oxygen to be resorbed).
371	Reactor, ROven, Begin, 800, 0, 255 Loop, , Begin, 12, , Aux Data, tOven, , , , Aux Data, tPIPE, , , , Aux Data, tR5, , , , Aux Data, pG4, , , , Aux Data, pG5, , , , Aux Data, AD590, , , , Time Delay, , , , 20, Loop, , End, , ,	Heat the sample at full power for 4 minutes with a target temperature of +800°C. Monitor the temperature of the sample oven, transfer pipe and R5. Monitor the pressure in both manifolds

372	Reactor, ROven, End, , , Heater (pwm), PIPE, End, , , Time Delay, , , , 1, Reactor, R5, Begin, 750, 0, 255	End sample combustion. Switch off ROven and transfer pipe heater. Switch on R5 at full power, target temperature +750°C. R5 will begin to resorb oxygen.
375	Loop, , Begin, 3, , Aux Data, tR5, , , , Aux Data, AD590, , , , Aux Data, i5V, , , , Aux Data, i28V, , , , Time Delay, , , , 1, Loop, , End, , ,	Measure temperatures of the R5 and sample oven. Measure the currents on the 5.2V and 28V voltage rails