AMSAT PHASE 3D TELEMETRY

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Contents

1. DOCUMENT SOURCE

Status: Provisional; items marked ?? are subject to finalisation.
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Location: A current version of this document is held at:

http://www.amsat-dl.org/p3d/tlmspec.txt
http://www.amsat-dl.org/p3d/pubtelem.zip

2. INTRODUCTION

The P3 flight computer (IHU-1) uses a radiation hardened Cosmac CDP-1802 microprocessor running at 100K instructions/s. The operating system is called IPS, an acronym that translates as "Interpreter for Process Structures".

A small area of the computer's 64K memory is used by IPS as workspace. This is filled with 256 bytes of data collected via a 128 channel ADC, and 128 bytes of digital data, the IPS "Syspage". This document describes these 256 bytes, and provides support material and pointers to related information.

Of necessity many abbreviations are used. Please refer to the Glossary.

In the IPS language "#" is used to indicate a hexadecimal number.
For example #200 = 0x200 = 512.

3. FREQUENCIES

AO-40 transmits its telemetry at 400 bps using PSK. Frequencies used are:

BEACON	General Beacon (GB)	Middle Beacon (MB)	Engineering Beacon (EB)	Note
2 m	----	145.898 MHz	----	1
70cm	435.450 MHz	435.600 MHz	435.850 MHz	2
13cm(1)	2400.200 MHz	2400.350 MHz	2400.600 MHz	3
13cm(2)	----	2401.323 MHz	----	
3cm	10451.000 MHz	10451.150 MHz	10451.400 MHz	4
1.5cm	24048.000 MHz	24048.150 MHz	24048.400 MHz	
IR Laser	----	~360 THz	----	5

The Middle beacon is on most of the time and carries IHU-1 telemetry.

The Middle beacon is also used by the IHU-2 telemetry. But when the IHU-2 is powered off, the Middle beacon carries IHU-1 GB data. Beacons can be turned on and off in almost any combination.

The IHU-2 can also "listen" to IHU-1 and if desired, repeat its blocks by software on its MB assignment.

The Beacons' relative powers are GB 0db, EB +4db, MB +10db.

Notes:

1. The 2m TX has been non-functional since 2000 Dec 26.
2. The 70cm TX has been non-functional since 2000 Nov 16 (launch).
3. The S1 TX has been non-functional since 2001 Aug 13
4. The X TX appears defunct.
5. Not tested.

4. MODULATION FORMAT

The spacecraft digital information at 400 bits/sec is first differentially encoded so that a message "1" is represented by a change in the data stream, and a message "0" by no change. This data is then exclusive-ored with its 400 Hz clock to create Manchester coding. Finally this stream is passed through a gentle low pass filter (3 db point = 560 Hz) to restrict extraneous sidebands and then balanced modulated onto the RF carrier to create PSK.

Differential encoding is used, similar to packet radio systems, to ensure that channel and decoder polarity inversions are of no consequence; it's the changes that matter, not the absolute polarity.

5. AMSAT P3 BLOCK STRUCTURE

AO-40 (like all P3-Satellites) transmits 512 byte blocks preceded by a synchronisation sequence and followed by a checksum (CRCC):

```
                bytes
                -----
Sync:             4    #39 #15 #ED #30
Block:          512     - see descriptions
CRCC:             2     - see definition
Inter-block:   ~130    #50
```

A byte consists of 8 bits and is transmitted serially, MSbit first at a rate of 50 byte/s. Note: 50 Hz is the standard rate for an IPS operating system clock and interrupts.

6. AO-40 BLOCK CONTENTS

Blocks are identified according to the first byte of the block (followed by <space>, e.g. "M ", "A " etc.

A blocks carry 128 analogue and 128 digital telemetry channels.

E blocks carry data as per A-block, but are historic events.

K, L, M, N blocks are message blocks (flying mailbox) from one command station to another, but also used for broadcast. All characters use ASCII representation. Bit 7 set to 1 may be used to indicate highlighted character display. No CR/LF is transmitted; they should be inserted at the ground after 64 received characters.

X blocks are received when the spacecraft's operating system is being loaded.
The 3rd byte is a letter (A,B,C ...) which indicates the latest block of approximately 15 successfully received.

D blocks contain data dumps in 500 byte packets, plus 12 housekeeping bytes.

All other blocks are command acknowledgements, and include a comment that indicates this.

7. AMSAT P3 CRCC DEFINITION

```
         M             L
        .----------------.
 +--<---| | | | | | | | | DATA
 |      '----------------'
 |
(+)--------->-----+-------------->------------+-------->--------+
 |                |                           |                 |
 |   .--------.   |    .--------.   .------.  |    .----------. |
 +-<-| | | | |<--(+)<--| | | | |<--| | | |<--(+)<--| | | | | |<-+
     '--------'        '--------'   '------'       '----------'
     <--------- M S B --------->   <--------- L S B --------->
```

CRCC MSByte sent first, then LSByte.   (+) means "EXOR"

The initial value of the CRCC register is hex FFFF
Note: that calculating a crcc of a block that already includes a correct crcc as the last 2 last bytes, results in a net crcc = 0 because 16 "0"s are input to the crcc register!

The AMSAT CYC2 (x^16 + x^12 + x^5 + 1) definition is similar to, but not the same as, CCITT CRC16

8. AO-40 BLOCK FORMATS

A-Block format
~~~~~~~~~~~~~~

```
+----------------------------------------------------------------+
|A  HI, THIS IS AMSAT OSCAR-40       yyyy-mm-dd  hh:mm:ss  #nnnn |
| text messages                                                  |
| text messages                                                  |
| text messages                                                  |
|aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa|
|aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa|
|dddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddd|
|dddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddd|
+----------------------------------------------------------------+
```

Notes:

1. "yyyy-mm-dd" is the UTC date.
2. "hh:mm:ss" is UTC time
3. "#nnnn" is the command number in hexadecimal.
4. "aaaaa" is 128 bytes of analogue telemetry from memory #380 - #3FF
5. "ddddd" is 128 bytes of digital data from memory #400 - #47F
6. "text messages" is up to 192 bytes of ASCII plaintext. Use optional.
7. Blanks are #20.
~~~~~~~~~~~~~~

E-block format
~~~~~~~~~~~~~~

An "Event" is an occurrence, benign or otherwise, in the spacecraft,
when the spacecraft's state was grabbed and stored for later examination.

```
+----------------------------------------------------------------+
|E  HI, THIS IS AMSAT OSCAR-40       yyyy-mm-dd  hh:mm:ss  #nnnn |
|                                                                |
|EVENT #eeee                                                     |
|                                                                |
|aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa|
|aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa|
|dddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddd|
|dddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddddd|
+----------------------------------------------------------------+
```

Notes:

1. The block format is identical to an "A " block except for:

   1.1. The block identifier is "E "
   1.2 Date, time and command number refer to the Event
   1.3. No text message
   1.4. The textual reference on line 2, e.g. EVENT #0042

Whole Orbit Dump Format (WOD)
~~~~~~~~~~~~~~~~~~~~~~~~~~~

A specified telemetry point can be monitored at regular MA intervals and downloaded in a text block.
Example:

```
+----------------------------------------------------------------+
|K  Whole Orbit Data V1.2   Samples: 1    Captured Channel: #019B|
|gggggg..........................................................|
|.......................................;;;....;;................|
|...............    ............;;...;;.....;.;.;.;;.............|
|................................................................|
|........................;;;...;;....wwwwww................gg....|
|.......                                                         |
|Start= 13:54:56 8465  #9FC0     Last= 13:59:32 8466  #A106      |
+----------------------------------------------------------------+
```

Notes:

1. Line 1: Samples: [n] specifies the sample interval in MA units (/256) Captured Channel: [n] specifies the telemetry channel number

2. Line 2 - 7: 384 sampled values. Range is 0-255, so some values will be unprintable as ASCII. Block is initialised with value 32, i.e. <space>

3. Line 8 Start= hh:mm:ss dddd #oozz Last= hh:mm:ss dddd #oozz

These give the day (dddd), time (hh:mm:ss), orbit number (#oo), and MA (#zz) when the capture program was initiated, and similarly for the last point. When the block is complete, "Last=" is replaced with "End ="

3.1 Day means Amsat Day Number, and 0 = 1978 Jan 01. Time is UTC.
3.2 Orbit number is in hexadecimal, and only its LS byte is given.
3.3 MA is in hexadecimal.

4. Sampling actually occurs on an MA that is exactly divisible by Samples, i.e. when MA MOD SAMPLES = 0

D-block Format
~~~~~~~~~~~~~

D-blocks are in a format to allow transfer of long data files. This format has been devised to allow error free transfer of files in either upload or download mode. The file is split into blocks (or packets) which contain the minimum amount of housekeeping to enable the original file to be re-assembled.

To that end, the packet contains an Amsat block ID, file ID, total number of blocks in sequence, sequence number, byte count and checksum. This requires 12 bytes; the remaining 500 bytes are file data.

Thus a packet contains sufficient information for any D-block to be mapped into the output file, independent of the order in which the blocks are received.

The data content is arbitrary, but it is assumed that the mapping from source data to D-blocks will be essentially sequential. That is to say, the first block contains file bytes 0-499, the second 500-999 and so on. However this is only a convention, and alternative relationships are not proscribed.

Bytes	Information	Notes
0,1	"D " Block Identifier, i.e. #44, #20	1
2,3	File ID	2
4,5	Number of blocks in sequence, NB	3
6,7	Sequence Number, NS	4
8-507	500 data bytes, randomised	5
508,509	Number of bytes in this block, N	6
510,511	CRC checksum	7

Notes:

1. The Block Identifier is used as a distinguishing mark by telemetry display software or as an IPS command for uploads.

2. The File ID is two arbitrary bytes which identify the source material. These bytes might well be printable ascii values, e.g "JM", and perhaps be incorporated into the output filename, e.g. DUMP_JM.DAT Their use is optional, but recommended.

3. The number of blocks in a sequence is normally NB = (FileLength DIV 500)+1

4. Each D-block has a unique Sequence Number NS which takes values from 0 to NB-1. This tells you where to position the Data Bytes into the output file.

5. The contents of the data byte field would typically be 500 bytes from the source file, starting at offset NS*500. The data byte field is crudely randomised by EXORing each byte with the block position pointer. Thus the first data byte is EXORed with 0x08, the next with 0x09 and so on up to 0xFB.

6. The number of bytes in a block would normally be 500, with some other value for the last block in the sequence. For example, a file of 1024 bytes would be split into three blocks (NB=3) with N = 500, 500 and 24 bytes respectively.

7. The inner CRC checksum is optional since the block already had an outer checksum. However it might be useful for users of older 512 byte telemetry decoders where the outer checksum is discarded.
~~~~~~~~~~~~~

9. AO-40 Telemetry List Analogue #100-#17F

Notes:

1. For IHU memory address, add #280 to telemetry position address.

2. [NOT ASSIGNED] means nothing is wired to the analogue multiplexer.

3. Since 2000 Dec 26, 8 temperature and 9 current channels are non-functional. They are marked **

```
Telem
Addr   Name                     Translation
Hex                             Equation
---------------------------------------------------------------------------
#100   SEU Spin - Analog       X>101 :  RPM = (X/150.3033938)^-5.032524347
                               X<=101:  RPM = 46.4720 - 0.38452*X
                               Alternative:
                               RPM = -1.3867E-6*X^3 + 0.004702*X^2
                                     -1.216*X + 83.67
#101   EPU Motor Pressure      Bar = 0.0815 * X - 1.253
#102   EPU Tank Pressure       Bar = 0.0835 * X - 1.381
#103   EPU - Motor Amps        I = 0.0503 * X - 0.3154
#104   EPU - Motor Voltage     V = 1.221 * X - 263.0537
#105   EPU - Flow              Use raw
#106   I-Bat, Tot Bat Amps     I = 0.2410 * X - 31.28
#107   I-28-U1, EPU amps       I = 0.2035 * X - 2.85
#108   I-28-U2, Main Bus       I = 0.197 * X -0.739
#109   I-28-U3, 28v-S amps     I = 0.0412 * X -0.76
#10A   I-28-BCR, BCR amps      I = 0.1024 * X -0.653
#10B   Volts - Main Battery    V = 0.1548* X -1.484
#10C   Volts - Aux. Battery    V = 0.1548* X -1.484
#10D   Volts - 28V Bus         V = 0.1548* X -1.484
#10E   Volts In - BCR-1        V = 0.1522* X -1.06
#10F   Volts In - BCR-3        V = 0.1318* X -0.923
#110   10V - C2 - BCR-3        V = 0.0657* X - 0.712
#111   Volts In - BCR-2        V = 0.1318* X -0.923
#112   10V - C1 - BCR-2        V = 0.0657* X -0.712
#113   Motor Valve Position    X<=89, closed
#114   400N Hi. Press.         Bar = 2.3406* X - 197.1
#115   400N Low Press.         Bar =0.1235* X -1.235
#116   AGC - L2 Rx             AGC= 0.154* X -10.6
#117   Power Out - X Tx        Use raw
#118   ComStates - X Tx        States added via resistors; decode thus:
                                C=150: TWT_OFF, FIL_OFF,    OVR_OFF
                                C=170: TWT_ON,  FIL_ON,     OVR_ON
                                C=200: TWT_ON,  FIL_ON/OFF, OVR_OFF/ON
                                C=250: TWT_ON,  FIL_OFF,    OVR_OFF

#119   Milliamps Helix X Tx    mA = 0.103*X -0.95
#11A   Power K Tx              Use raw
#11B   AGC S2 / C Rx           AGC= -0.011*X^2 + 3.66*X - 284
#11C   AGC HF Rx               Use raw
#11D   AGC S1 Rx               AGC= -0.004*X^2 + 1.25*X -  72
#11E   AGC V - Rx              AGC= 0.254* X - 14.8
#11F   AGC U - Rx              AGC= 0.457* X - 31.9
#120   AGC L1 - Rx             AGC= 0.129* X - 7.9
#121   ---
#122   Power S-PA & Mix        Use raw
#123   Power V - Tx            Use raw
#124   AGC V - Tx              Use raw
#125   Power U - Tx PA         Use raw
```

```
#126   ALE U - Amp            Use raw
#127   ---
#128   ---
#129   Ant R1 position        See also #189 bits 0,1
                              States added via resistors; decode thus:
                                X=253, VRx=Hi, VTx=om, URx=Hi, UTx=om
                                X=205, VRx=om, VTx=Hi, URx=Hi, UTx=om
                                X=173, VRx=Hi, VTx=om, URx=om, UTx=Hi
                                X=150, VRx=om, VTx=Hi, URx=om, UTx=Hi
#12A   ---
#12B   Temp - X Tx            T= -0.413*X +103.8
#12C   Temp TWTA X Tx         T= -0.413*X +103.8
#12D   U/D Z SunSens          X>128 = above Y-X plane
#12E   SunSens Z - 25         SA= -31.501 + (0.3682*X) + (-0.001539 * X^2
                                          + (0.00000361 * X^3)
#12F   SunSens Y - 25         SA= -31.501 + (0.3682*X) + (-0.001539 * X^2
                                          + (0.00000361 * X^3)

#130   SunSens Up - X         SA = ArcCos(X / 255)
#131   SunSens Up - Y         SA = ArcCos(X / 255)
#132   SunSens Dwn - X        SA = ArcCos(X / 255)
#133   SunSens Dwn - Y        SA = ArcCos(X / 255)
#134   SunSens Z - 45         SA= -55.179 + (0.64187*X) + (-0.002447 * X^2
                                          + (0.00000581 * X^3)

#135   SunSens Y - 45         SA= -55.179 + (0.64187*X) + (-0.002447 * X^2
                                          + (0.00000581 * X^3)

#136   SunSens 25 - valid     Valid = >245
#137   SunSens 45 - valid     Valid = >245
#138   Pwr S-band 2 Tx        Use raw
#139   AGC S-band 2 Tx        Use raw
#13A   ARU Bridge A           ]  X<=15  ARU open,   array stowed
#13B   ARU Bridge B           ]  X >15  ARU closed, array released
#13C   [NOT ASSIGNED]
#13D   [NOT ASSIGNED]
#13E   [NOT ASSIGNED]
#13F   [NOT ASSIGNED]
#140   Temp - SEU             T = 0.659 * X -69.7
#141   Temp - EPU             T = 0.659 * X -69.7
#142   Temp - BCR #1          T = 0.659 * X -69.7
#143   Temp - BCR #3          T = 0.659 * X -69.7
#144   Temp - BCR #2          T = 0.659 * X -69.7
#145   Temp - MMH - Bay 3     T = 0.659 * X -69.7
#146   Temp - Aux Bat Bay 5   T = 0.659 * X -69.7
#147   Temp - Aux Bat Bay 1   T = 0.659 * X -69.7
#148   Temp - NH3 Bay 2       T = 0.659 * X -69.7
#149   Temp - Main bat Bay 2  T = 0.659 * X -69.7
#14A **Temp - Main bat Bay 4  T = 0.659 * X -69.7
#14B **Temp - Main bat Bay 6  T = 0.659 * X -69.7
#14C   Temp - SolPanl - 1     T = 0.659 * X -69.7
#14D   Temp - SolPanl - 2     T = 0.659 * X -69.7
#14E   Temp - SolPanl - 3     T = 0.659 * X -69.7
#14F   Temp - SolPanl - 4     T = 0.659 * X -69.7
#150   Temp - SolPanl - 5     T = 0.659 * X -69.7
#151   Temp - SolPanl - 6     T = 0.659 * X -69.7
#152   Temp - L2 Rx           T = 0.659 * X -69.7
#153   Temp - HP 2 +X -Y      T = 0.659 * X -69.7
#154 **Temp - HP 2 -X         T = 0.659 * X -69.7
#155   [NOT ASSIGNED]
#156   Temp - S2-C Rx         T = 0.659 * X -69.7
#157   Temp - S1-HF Rx        T = 0.659 * X -69.7
#158   Temp - U Tx Exciter    T = 0.659 * X -69.7
```

```
#159   Temp - U & V Rx        T = 0.659 * X -69.7
#15A   Temp - L1 Rx           T = 0.659 * X -69.7
#15B   Temp - S1 Tx           T = 0.659 * X -69.7
#15C   Temp - S2 Tx           T = 0.659 * X -69.7
#15D   [NOT ASSIGNED]
#15E   Temp - V Tx            T = 0.659 * X -69.7
#15F   Temp - U Tx PA         T = 0.659 * X -69.7
#160   [NOT ASSIGNED]
#161   Temp - IHU             T = 0.659 * X -69.7
#162 **Temp - Top             T = 0.659 * X -69.7
#163 **Temp - Bottom          T = 0.659 * X -69.7
#164 **Temp - Back            T = 0.659 * X -69.7
#165   Temp - Side 4 panl     T = 0.659 * X -69.7
#166   Temp - HP 4 +X +Y      T = 0.659 * X -69.7
#167   Temp - HP 3 -X         T = 0.659 * X -69.7
#168   Temp - HP 2 +X +Y      T = 0.659 * X -69.7
#169   Temp - HP 1 +X -Y      T = 0.659 * X -69.7
#16A   Temp - HP 3 +X         T = 0.659 * X -69.7
#16B **Temp - N2O4 -X -Y      T = 0.659 * X -69.7
#16C   Temp - N2O4 +X +Y      T = 0.659 * X -69.7
#16D   Temp - Side 2 panl     T = 0.659 * X -69.7
#16E   Temp - S ant.          T = 0.659 * X -69.7
#16F **Temp - Helium Tank     T = 0.659 * X -69.7
#170 **I - 28v - SEU          Use raw
#171 **I - SA-1 - BCR - 1     I = 0.1014 * X -0.6212
#172 **I - SA-6 - BCR - 1     I = 0.1014 * X -0.6212
#173 **I - SA-3 - BCR - 3     I = 0.1014 * X -0.6212
#174 **I - SA-2 - BCR - 3     I = 0.1014 * X -0.6212
#175 **I - 10V - C2 - BCR 3   I = 0.0125 * X -0.0875
#176 **I - SA-4 - BCR - 2     I = 0.1014 * X -0.6212
#177 **I - SA-5 - BCR - 2     I = 0.1014 * X -0.6212
#178 **I - 10V - C1 - BCR 2   I = 0.0125 * X -0.0875
#179   I - K - Tx             Use raw
#17A   I - 28V - S PA/Mix     I = 0.0429 * X - 0.333
#17B   I - 10V - S PA/Mix     Use raw
#17C   [NOT ASSIGNED]
#17D   [NOT ASSIGNED]
#17E   [NOT ASSIGNED]
#17F   [NOT ASSIGNED]
```

Additional Notes to the above

```
#105      Unknown/Karl
#117      This output is highly temperature sensitive. It indicates output,
          but cannot be calibrated.
#11A      Unknown/Danny
#11C      Unknown/Matjaz
#122-#126 Unknown/Werner
#127
#12E/F    new equation derived in lab; old theoretical equation:
            SA = atan((X-128) /274) * 180/Pi
#134/5    new equation derived in lab; old theoretical equation:
            SA = atan((X-128) /128) * 180/Pi
#138/9    Unknown
#155      -used to be K Tx
#15D      -used to be 10 dig. Tx-
#160      -used to be RF monitor-
#170      Unknown
#175      This was never accurately measured.....
#179      Unknown
#17B      Unknown
```

10. AO-40 Digital Telemetry List #180 - #1FF

Notes: 1. For SYSPAGE address (#400 on), add #280 to telemetry position address.

2. Bits or bytes marked "---" are unused.

```
TLM
Addr  Byte Name          Meaning
-------------------------------------------------------------------
#180  Temporary          Used by 2MUX handler.

                         Note: 2MUX[i] commanded with  #NN i !S

#181  EPU Configuration  2MUX[1]
                         bit   significance
                         ------------------
                         0 LSB Gas generator ON/Configuration ON
                         1     EPU run
                         2     Flow control 1. valve C
                         3     Flow control 2. valve B
                         4     ---
                         5     Input  valve A
                         6     Output valve B
                         7 MSB Output valve C

#182  LIU Power          2MUX[2]  #AA = LIU power ON, all else is OFF

#183  EPU - Power        2MUX[3]  #AA = EPU power ON, all else is OFF

#184  X-Tx Control       2MUX[4]
                         bit   significance
                         ------------------
                         0 LSB AGC 0
                         1     AGC 1
                         2     AGC 2
                         3     AGC 3
                         4     ---       ) Controls   ??
                         5     ---       ) reset      ??
                         6     TWTA C0 = filament boost On control
                         7 MSB TWTA C1 = helix overcurrent limit override

                         TX   ON  is 3,4MUX[5], bit 5
                         TWTA ON  is 3,4MUX[5], bit 13

#185  EPU - Current set  2MUX[5]  #32 = 80% current; 0 = highest current
                                  CURRENT = 10.337 - 0.0366*X

#186  EPU - Flow rate    2MUX[6]  #00 = min flow rate   ?? Ask Dieter Zube
```

```
#187  Wheel power        2MUX[7]
                         bit   significance
                         ------------------
                         0 LSB   Wheel 1 power ON
                         1       Wheel 2 power ON
                         2       Wheel 3 power ON
                         3       -----+
                         4       ----+|
                         5       ---+||
                         6       --+|||
                         7 MSB   -+||||
                                  |||||
                                  01010 = EPU configuration ON

                         NOTE:
                         Before turning wheel power ON,
                         speed must be set to #5FFE (0 rpm)

                         Wheel controller will ignore OFF command
                         until wheels have stopped spinning

                         NEVER turn OFF 28V-S with wheels running;
                         wheels must be despun to #5FFE


#188  Experiment         2MUX[8]
      control            bit   significance
                         ------------------
                         0 LSB ARU ON     (Array Release Unit)
                         1     Rudak ON
                         2     GPS ON
                         3     Mon Rx ON
                         4     A CAM ON
                         5     B CAM ON
                         6     Cedex control ON
                         7 MSB Cedex power ON

                         Note: IHU-2 ON is 3,4MUX[5], bit 8.
                               For Monitor pre-amp to be ON,
                               21/24 MHz RX must be ON.

#189  Antenna            2MUX[9]
      control            bit   significance
                         ------------------
                         0 LSB V rx to omni, V tx to higain
                         1     U rx to omni, U tx to higain
                         2     L-band omni preamp on   ) if bit2 & bit3 = 0
                         3     L-band higain preamp on ) then both are ON
                         4     ---
                         5     ---
                         6     ---
                         7 MSB ---

                         Note: See TLM byte #129 for antenna R1 position
```

```
#18A SEU ES                2MUX[A]
     Sensitivity           bit   significance
                           ------------------
                           0 LSB  20mV
                           1      37mV      Hysteresis 200mV
                           2      75mV      Threshold  600mV
                           3     150mV
                           4     300mV
                           5     600mV
                           6     1.2V
                           7 MSB 2.4V

#18B  PSU Relay            2MUX[B]
      control              bit   significance
                           ------------------
                           0 LSB main battery ON       ) if bit0 & bit1 = 0 then
                           1     aux  battery ON       ) aux and main battery ON
                           2     charger ON aux/main
                           3     auxiliary heater ON
                           4     ---
                           5     ---
                           6     ---
                           7 MSB ---

                           Charger charges whichever batteries are NOT active.
                           Note: The heater must be toggled on and off every
                           20ms to function.

#18C  Battery voltage      2MUX[C]  if X<64 then X+=256  ; Offset = 0.04*X +17.76
                            offset

#18D  BCR-1 Array          2MUX[D]  if X<128 then X+=256 ; Offset = 0.10*X - 5.6
                            voltage offset

#18E  BCR-2 Array          2MUX[E]  if X<128 then X+=256 ; Offset = 0.10*X - 5.6
                            voltage offset

#18F  BCR-3 Array          2MUX[F]  if X<128 then X+=256 ; Offset = 0.10*X - 5.6
                            voltage offset

#190  SS1 (count)          C=255 or C=0, PLL locked.  Sun-Sensor angular position
                            oscillator, Slit antenna side.

#191  SS2                  Time offset from SS-1, counts

#192  SS-Flags             Sun sensor service flag
                           bit   significance
                           ------------------
                           0 LSB SS1
                           1     SS2

#193  Spin-count, raw      Updated every 20ms. Spin angle relative to SS1
```

```
#194  Beacon control      OUT 7
                          bit   significance
                          ------------------
                          0 LSB GB OFF
                          1     GB FSK (1=+170Hz)
                          2     DPSK OFF
                          3     EB ON
                          4     --+ PSK source
                          5     -+| for GB (EB: don't care)
                                 ||
                                 00 - no PSK
                                 01 - ranging
                                 10 - EB source
                          6     --+ MUX-CTRL for sensor elec. module
                          7 MSB -+|
                                 ||
                                 00 - Sun data
                                 01 - spin ref./spin counter
                                 10 - ES top    beam
                                 11 - ES bottom beam

#195  Schiel-Korrektur    SS correction (SS1+SS2)/2  (see also #1DD)

#196  ES1                 Earth sensor ; Z      at last top    ES pulse
#197                                   ; Orbit#  "  "     "    "    "    MOD 256
#198  ES2                 Earth sensor ; Z      at last bottom ES pulse
#199                                   ; Orbit#  "  "     "     "    "   MOD 256

#19A  ES lockout range    Within +- C counts from sun sensor pip, earth
                          sensor handler ignores data
                          (Spin count 1 circle = 256 counts.)

#19B  ES1                 Spin count at edge selected, top beam.

#19C  Update Flag1        Indicates updating, top beam.
                          Alternate: when in 3-axis mode means +X in view

#19D  ES2                 Spin count at edge selected, bottom beam.

#19E  Update Flag2        Indicates updating, bottom beam.
                          Alternate: when in 3-axis mode means -X in view

#19F  Sensor mode         1 = spin, 0 = 3-axis

#1A0  MODUS               bit   significance  (magnet control)
                          ------------------
                          0     magnet system is on
                          1     undespun magnet

#1A1  M-Soll              magnet vector desired angle to the despun Sun
                          (clockwise as seen from top, 1 circle = 256)

#1A2  M-Out               OUT 3
                          bit   significance
                          ------------------
                          0 LSB current polarity Arm 1
                          1     current polarity Arm 2
                          2     current polarity Arm 3
                          3     Magnet power ON
                          4     IR (laser) beacon ON
                          5     ---
                          6     ---
                          7 MSB ---
```

```
#1A3  Z-FRAC-lo          Fractional Z increment in 20ms
#1A4  Z-FRAC-hi            Counts down to 0 from preset value.
                           255th Z has different value of Z-FRAC.
                           ~8046 counts/Z for 11.44 hour orbit

#1A5  O/256              Z from perigee (i.e. MA)

#1A6  O#-lo              Orbit number
#1A7  O#-hi

#1A8  UHR                10ms             UTC
#1A9                     sec
#1AA                     min
#1AB                     hour
#1AC                     day              1978 Jan 01 = AMSAT day 0.
#1AD                     256day
#1AE  SU0                10ms             IPS stopwatch 0.
#1AF                     sec
#1B0                     min
#1B1                     min*256
#1B2  SU1                10ms             IPS stopwatch 1.
#1B3                     sec
#1B4                     min
#1B5                     min*256
#1B6  SU2                10ms             IPS stopwatch 2.
#1B7                     sec
#1B8                     min
#1B9                     min*256
#1BA  SU3                10ms             IPS stopwatch 3.
#1BB                     sec
#1BC                     min
#1BD                     min*256
#1BE  ---                not used
#1BF  MUX flag           1 = do mux control

                   Note: 3,4MUX[i] commanded with #**NN  i !W (LSB)
                                                  #NN**  i !W (MSB)
                                        where ** is existing byte.

#1C0 Wheel-1 -lo         3,4MUX[1]         rev/min
#1C1  speed  -hi         Speed =  960/19 * 2.4e6 * (1/(C+2) - 1/0x6000)

#1C2 Wheel-2 -lo         3,4MUX[2]         rev/min
#1C3  speed  -hi         Speed =  960/19 * 2.4e6 * (1/(C+2) - 1/0x6000)

#1C4 Wheel-3 -lo         3,4MUX[3]         rev/min
#1C5  speed  -hi         Speed =  960/19 * 2.4e6 * (1/(C+2) - 1/0x6000)

#1C6 SEU control -lo     3,4MUX[4]
     LIU/EPU on          bit   significance
                         ------------------
                         0 LSB ES select side pointing (spin mode)
                         1     ES select top pointing (3-axis mode)
                         2     Earth sensor positive edge select.
                               (Strobes value of spin count at transition.)
                         3     LIU + EPU instrumentation ON.
                         4     0.3V Sun Sensor Sensitivity
                         5     0.6V  "    "         "
                         6     1.2V  "    "         "
                         7     2.4V  "    "         "
                               (Max threshold #F = 1 solar constant)
```

```
 #1C7 SEU control -hi     8     25 deg sensor + omni
                          9     45 deg sensor
                          10-15 ---
                          Note: This byte needs to be updated in all routines.

 #1C8 Transmitter         3,4MUX[5]
      control -lo         bit   significance
                          ------------------
                          0 LSB  S2 tx on
                          1      ---
                          2      U tx exciter only - i.e. low power (*)
                          3      ---
                          4      ---
                          5      X  Tx - solid state
                          6      Ku Tx - EB
                          7      ---
 #1C9 Transmitter          8     IHU-2  ON
      control -hi          9     V  Tx  ON  )  Only one may be
                          10     U  Tx  ON  )  on at a time
                          11     S1 Tx  ON
                          12     ---
                          13     X TWTA ON
                          14     Ku Tx  ON
                          15 MSB ---

                         * Bit 10 must also be set to 1 for the U-band Tx to be

in low power mode.
                           V Rx must be ON to enable the U Tx. (See #1CA)
                           S2 Tx IF is shared with the Ku Band Tx.
                           Never turn the TWTA off until it has fully cycled on!

 #1CA Receiver            3,4MUX[6]
      control -lo         bit   significance
                          ------------------
                          0 LSB  21 MHz Rx on
                          1      24 MHz Rx on
                          2      V Rx on / U Rx off (*)
                          3      S2 Rx on
                          4      ---
                          5      L2 Rx on
                          6      S1 Rx on
                          7      C Rx on
 #1CB Receiver            8-15   ---
      control -hi
                          * V Rx must be ON to enable U Tx.

 #1CC Matrix control -lo  3,4MUX[7]
                           bit   significance
                          ------------------
                          0-7    )  See #1F2 - #1FF for
 #1CD Matrix control -hi  8-11   )  Matrix set-up format
                          12     Column bit C0
                          13     Column bit C1
                          14     Column bit C2
                          15     ---

 #1CE ---            -lo  3,4MUX[8]
 #1CF ---            -hi
```

```
#1D0 LEILA1 control -lo  3,4MUX[9]
                          bit   significance
                          ------------------
                          0 LSB  )
                          1      )  Threshold
                          2      )   0 - 15
                          3      )
                          4      0 = Scan reset; 1 = Scan
                          5      0 = Auto;       1 = IHU control
                          6      0 = Jam off;    1 = Jam
                          7      0 = Notch off;  1 = Notch
#1D1 LEILA2 control -hi   8      )
                          9      )  Threshold
                         10      )   0 - 15
                         11      )
                         12      0 = Scan reset; 1 = Scan
                         13      0 = Auto;       1 = IHU control
                         14      0 = Jam off;    1 = Jam
                         15 MSB  0 = Notch off;  1 = Notch

                         Note: Normal mode = #D8
                               Bent pipe   = #1F

#1D2 spare          -lo  3,4MUX[A]
#1D3 spare          -hi

#1D4  ---                )
#1D5  ---                ) not used
#1D6  ---                )

#1D7 A/D control         OUT 5  ADC channel selector; updated every 20ms

#1D8 T/Z                 PSK inter-block gap counter/flag

#1D9 S/C Status          IN E
                         bit   significance
                         ------------------
                         0 LSB  LIU power ON
                         1      S/A plug status 1 = Armed, 0 = Safe
                         2      EPU power
                         3      ---
                         4      ---
                         5      memory soft error count bit 0
                         6        "     "     "     "   bit 1
                         7 MSB    "     "     "     "   bit 2

#1DA Input A/B   -lo     IN A ) Multiplexed input, 16 bit data
#1DB Input A/B   -hi     IN B )      controlled by OUT 4,3

                         bit   significance
                         ------------------
                         0 LSB  ---
                         1      ---
                         2      Sync wheel #1
                         3      Sync wheel #2
                         4      Sync wheel #3
                         5-15   ---

#1DC ---                 not used

#1DD Korr. count         Spin angle relative to Sun
                         (Spin-count, raw) - (SS1+SS2)/2   [#193 - #195]
```

```
#1DE Event count - lo
#1DF Event count - hi

#1E0 Command#    - lo
#1E1 Command#    - hi

#1E2 Pl                   Counter in GB handler (RTTY)
#1E3 Ph                     "      "  "   "       "

#1E4 N CW speed           no. of 20ms per dot, morse speed.
#1E5 n CW speed           running count of units for morse.

#1E6 Status               ) Do not use
#1E7 OUT 7 temp           ) OUT 7 temp, only
#1E8 M                    ) temporary image!

#1E9 ---                  )
#1EA ---                  )  not used
#1EB ---                  )
#1EC ---                  )

#1ED E-FLAGS              bit   significance
     Emergency status     ------------------
                          0     Battery voltage low
                          1        ..      ..    very low
                          2     Command loss (Watchdog)
                          3     High temperature - transponder
                          4     Sun angle exceeds limit (~50 degrees)
                          5     ---
                          6     ---
                          7     ---

#1EE EXPFLAG -lo          Experiment status, in emergency power shutdown.

                          bit   significance    0 = normal
                          ------------------    1 = prevented from use
                          0 LSB  Laser
                          1      RF monitor
                          2      A CAM
                          3      B CAM
                          4      GPS
                          5      K Tx
                          6      X Tx
                          7      Passbands
#1EF EXPFLAG -hi          8      IHU-2
                          9      Rudak
                         10      Cedex control
                         11      Cedex power
                         12      Heater (fuel tanks)
                         13      ---
                         14      ---
                         15 MSB  ---
```

#1F0 TXFLAG -lo — Transmitter status, in emergency power shutdown.

0 = normal
1 = prevented from use

Address	bit	significance
#1F0 TXFLAG -lo	0 LSB	S2 Tx
	1	---
	2	U Tx (exciter)
	3	---
	4	---
	5	X Tx solid state
	6	---
	7	---
#1F1 TXFLAG - hi	8	---
	9	V Tx
	10	U Tx (pa)
	11	S1 Tx
	12	---
	13	X Tx TWTA
	14	Ku Tx
	15 MSB	---

The following 16 bit words record the state of the IF matrix.

Maintained explicitly by flight software (not IPS kernel).

Address	bit	significance
#1F2 IF matrix column 1	0 LSB	V Rx to U Tx
	1	V Rx to S1 Tx
	2	V Rx to 3 cm Tx
	3	V Rx to K/S2 Tx
	4	V Rx to Leila #1
	5	V Rx to Leila #2
	6	Rudak #1 to U Tx
	7	Rudak #1 to S1 Tx
#1F3 IF matrix column 1	8	Rudak #1 to 3cm Tx
	9	Rudak #1 to K/S2 Tx
	10	Rudak #1 to Leila#1
	11	Rudak #1 to Leila#2
	12	column#, bit 0 = 1
	13	column#, bit 1 = 0
	14	column#, bit 2 = 0
	15 MSB	---

Address	bit	significance
#1F4 IF matrix column 2	0 LSB	21/24 MHz Rx to V Tx
	1	21/24 MHz Rx to S1 Tx
	2	21/24 MHz Rx to 3cm Tx
	3	21/24 MHz Rx to K/S2 Tx
	4	21/24 MHz Rx to Leila#1
	5	21/24 MHz Rx to Leila#2
	6	U Rx to V Tx
	7	U Rx to S1 Tx
#1F5 IF matrix column 2	8	U Rx to 3cm Tx
	9	U Rx to K/S2 Tx
	10	U Rx to Leila#1
	11	U Rx to Leila#2
	12	column#, bit 0 = 0
	13	column#, bit 1 = 1
	14	column#, bit 2 = 0
	15 MSB	---

```
#1F6 IF matrix column 3  bit   significance
                         ------------------
                          0 LSB  Leila#1 to V Tx
                          1      Leila#1 to U Tx
                          2      Leila#1 to 3 cm Tx
                          3      Leila#1 to K/S2 Tx
                          4      Leila#1 to Leila#1
                          5      Leila#1 to Leila#2
                          6      S1 Rx to V Tx
                          7      S1 Rx to U Tx
#1F7 IF matrix column 3   8      S1 Rx to 3 cm Tx
                          9      S1 Rx to K/S2 Tx
                         10      S1 Rx to Leila#1
                         11      S1 Rx to Leila#2
                         12      column#, bit 0 = 1
                         13      column#, bit 1 = 1
                         14      column#, bit 2 = 0
                         15 MSB  ---


#1F8 IF matrix column 4  bit   significance
                         ------------------
                          0 LSB  Rudak#2 to V Tx
                          1      Rudak#2 to U Tx
                          2      Rudak#2 to S1 Tx
                          3      Rudak#2 to K/S2 Tx
                          4      Rudak#2 to Leila#1
                          5      Rudak#2 to Leila#2
                          6      Leila#2 to V Tx
                          7      Leila#2 to U Tx
#1F9 IF matrix column 4   8      Leila#2 to S1 Tx
                          9      Leila#2 to K/S2 Tx
                         10      Leila#2 to Leila#1
                         11      Leila#2 to Leila#2
                         12      column#, bit 0 = 0
                         13      column#, bit 1 = 0
                         14      column#, bit 2 = 1
                         15 MSB  ---


#1FA IF matrix column 5  bit   significance
                         ------------------
                          0 LSB  EB to V Tx
                          1      EB to U Tx
                          2      EB to S1 Tx
                          3      EB to 3 cm Tx
                          4      EB to Leila#1
                          5      EB to Leila#2
                          6      GB to V Tx
                          7      GB to U Tx
#1FB IF matrix column 5   8      GB to S1 Tx
                          9      GB to 3 cm Tx
                         10      GB to Leila#1
                         11      GB to Leila#2
                         12      column#, bit 0 = 1
                         13      column#, bit 1 = 0
                         14      column#, bit 2 = 1
                         15 MSB  ---
```

```
#1FC IF matrix column 6  bit   significance
                         ------------------
                          0 LSB  L2 Rx to V Tx
                          1      L2 Rx to U Tx
                          2      L2 Rx to S1 Tx
                          3      L2 Rx to 3 cm Tx
                          4      L2 Rx to K/S2 Tx
                          5      L2 Rx to Leila#2
                          6      MB to V Tx
                          7      MB to U Tx
#1FD IF matrix column 6   8      MB to S1 Tx
                          9      MB to 3 cm Tx
                         10      MB to K/S2 Tx
                         11      MB to Leila#2
                         12      column#, bit 0 = 0
                         13      column#, bit 1 = 1
                         14      column#, bit 2 = 1
                         15 MSB  ---


#1FE IF matrix column 7  bit   significance
                         ------------------
                          0 LSB  C/S2 Rx to V Tx
                          1      C/S2 Rx to U Tx
                          2      C/S2 Rx to S1 Tx
                          3      C/S2 Rx to 3 cm Tx
                          4      C/S2 Rx to K/S2 Tx
                          5      C/S2 Rx to Leila#1
                          6      L1 Rx to V Tx
                          7      L1 Rx to U Tx
#1FF IF matrix column 7   8      L1 Rx to S1 Tx
                          9      L1 Rx to 3 cm Tx
                         10      L1 Rx to K/S2 Tx
                         11      L1 Rx to Leila#1
                         12      column#, bit 0 = 1
                         13      column#, bit 1 = 1
                         14      column#, bit 2 = 1
                         15 MSB  ---
```

11. USER HARDWARE/SOFTWARE

This section by SM & JRM last updated 2001 Aug 05.

A good overview of latest available products and related telemetry resources is at:
http://www.amsat.org/amsat/sats/ao40/ao40-tlm.html

Hardware Demodulator

P3 400bps PSK Data Demodulator PCB unpopulated or made-up and tested is available from G3RUH:
http://www.jrmiller.demon.co.uk/products/p3dem.html

DSP Demodulators

DSP-2232 (Motorola DSP56001 chip)
No longer made, but came built in with 512 byte 400 bps PSK demodulator. Source of firmware updates: not known

DSP-12 (Motorola 56001 DSP chip)
The original had a 512 byte 400 bps PSK demodulator. Bent Bagger OZ6BL has modified this to 514 bytes.
ftp://ftp.tapr.org/dsp/Motorola/dsp56001/dsp-12/gce201.zip

DSP-93 (TI DSP chip)
TAPR site should have the should have files for the 400 bps PSK demodulator that does 514 bytes. IBM-PC software P3T, includes the *.obj files for this demodulator. At least one version of the demodulator is at:
ftp://ftp.tapr.org/dsp/Texas_Instruments/dsp93/software/p3c93t.zip

DSP-56002EVM
This board has flash RAM, it can be programmed to "wake up" as a 400 bps PSK demodulator, unlike the DSP-93 which always wakes up "dumb". ftp://ftp.tapr.org/dsp/Motorola/dsp56002/evm56k/bpsk400.zip

Telemetry Display Software

This is not a complete list, but represents as much as authors have informed the maintainer. In particular there are omissions in respect of IBM-PC DSP based software using sound cards(s).

IBM-PC

~~~~~~~

P3T

Written by W4SM. This is a Windows 95/98/NT/2000 "telemetry-only" version of P3TC as used by command stations. Available for a voluntary donation at:
http://www.cstone.net/~w4sm2/software2/P3t_AP.zip

Acorn Risc Computer

~~~~~~~~~~~~~~~~~~~

P3DTLM

Written by G3RUH for RiscOS, as used by command stations. Contact
mailto:g3ruh@amsat.org

Linux

~~~~~~

Written by OE1KIB and OE1VKW for Linux. "phase3" reads the 512 Byte blocks with or without CRC from a serial device (1200 Bd) and writes the (correct) blocks to stdout. "phase3c"(AO-13 telemetry) and "phase3d" (AO-40 IHU-1 telemetry) read from stdin and write in human readable format to stdout.
More details on http://cacofonix.nt.tuwien.ac.at/~kkudielk/Linux/ and there the archive phase3.tar.gz for source code and binaries.

Mac

~~~~

MacTLM by Gilbert Mackall can decode AO-40 telemetry, save RAW telemetry, save decoded telemetry, decode telemtry via the Internet, and has many other features:
http://www.goldensquare.net/MacTLM/

12. GLOSSARY

These notes explain the abbreviations and terms used in this document. *Lots* of additional information, which is essential reading may be obtained from:
http://www.amsat.org/amsat/sats/phase3d/
http://www.amsat-dl.org/p3d.html

+X -X +Y -Y +Z -Z
Refers to spacecraft coordinate axes. +X emerges perpendicular to the solar panels. +Z points out of the 400N motor nozzle (spin axis), and +Y completes a right-handed set, colinear with the winged solar panels. Also expressed in angular measures; see ALON ALAT.

10V
Ten volts; the power supply to IHU-1 flight computer, IHU-2, MUX etc.

21/24 MHz.
There are two 40 kHz wide HF receivers for user uplinks.

28 Twenty-eight volt power is supplied to the transmitters and other high power consumers, like the ATOS.

2MUX [n]
Secondary Multiplexer. Electronics that expands the OUT 2 instruction to give 8-bit control of up to 15 devices.

3,4MUX [n]
Another multiplexer that expands the OUT 3 and OUT 4 instructions to give 16-bit control of up to to 15 devices.

3-AXIS MODE
When commissioning is complete, the spacecraft will be non-spinning. Its orientation will be controlled by small rotations about each of the three principal axes. See SPIN-MODE, WHEEL and +X.

100mN
Thrust of ATOS motor. 1/4000th of the main motor, but can fire for long periods, giving significant velocity changes. Total delta-V available is ~600 m/s from 76 kg of ammonia NH3.

400N
Abbrev. for "the rocket motor". 400 Newtons is the nominal thrust. Since spacecraft launch mass is 632 kg, the motor can impart an initial acceleration of typ. 400/632 = 0.6 m/s^2 or ~0.06g. Total delta-V available is ~1100 m/s from 200 kg of MMH / N2O4 fuel.

A-CAM
Camera A. See SCOPE**.**

A/D , ADC
Analogue to digital converter. Associated with the flight computer is a multiplexer (MUX) that steps through voltages from 128 analogue sensors at a rate of 50 channels/s. The voltages are digitised to a resolution of 8 bits. The range is approximately, 0v = #07, 2.5v = #FC. The relationship between the ADC values and their sources is the substance of this document.

AGC
Automatic Gain Control. Indication of RX overload/attenuation in dB.

ALC
Automatic Level Control. Indication of TX overload

ALON ALAT

Attitude longitude and latitude. Orientation of the +Z axis with respect to the orbit plane. +Z (and the hi-gain antennas) pointed toward perigee is ALON=0, ALAT=0. Longitude is measured in the direction of spacecraft motion aound its orbit from perigee. Latitude is measured "up". Sometimes BLON/BLAT is used. B = Bahn = Germ. plane.

ARU

Array Release Unit. Electronics that releases the stowed solar panels so that they swing out to their operational "wing" position for 3-AXIS MODE.

ATOS

Arc-jet Thruster on Oscar Satellite. Ammonia propellant is heated by electric arc, then the heated gas is expanded via a nozzle and the thermal energy is converted into kinetic energy. Thrust is ~100 mN, giving an acceleration of order 0.0002 m/s^2. There is ammonia for about 500 hours of operation, offering a total delta-V of up to 470 m/s.

B-CAM

Camera B. See SCOPE.

BCR

Battery Charge Regulator. Three high efficiency redundant electronic modules accept power from 6 solar panels, and deliver it to the batteries and other systems.

C

C-band; the RX operates at ~5.7 GHz.

C1 C2 Continuous.

There are two redundant 10v power supplies, used by mission critical systems such as the IHU flight computer. Supplies are combined within a unit via diodes.

CEDEX

Cosmic-Ray Energy Deposition Experiment. The purpose is to characterise the space radiation environment as encountered by AO-40 over both short-term and long-term time-scales. The experiment consists of two sub-systems: the Total Dose Experiment (TDE) and the Cosmic Particle Experiment (CPE). Data via RUDAK.

CMD

Command; Command Number - count of uplinked commands.

CPE

The purpose of the CPE is to characterise the AO-40 (circa "Molniya") orbit radiation environment in terms of the observed particle Linear Energy Transfer (LET) spectrum inside the spacecraft.

CRCC

Cyclic Redundancy Checksum Characters. Two bytes added to data to enable the data's integrity to be verified.

CW

= "Morse code"; this can (optionally) be generated by software.

DPSK

Differential Phase Shift Keying. Encoding scheme where a message bit "1" is represented by a change in a level, and a "0" by no change. Also known as NRZ-M; see ARRL Handbook. The level then phase modulates a carrier by +/- 90 degrees.

EPU
Electric Propulsion Unit. Power Supply and electronics that manages the 100mN Arcjet (ATOS) thruster.

EB
Engineering Beacon. Higher powered telemetry beacon. See section on Frequencies.

E-FLAGS
Emergency Flags. A number of extreme conditions are checked for by the flight software and action taken. E-FLAGS reports the condition.

ES
Earth Sensor. Optical system that images the Earth onto photo-diodes. These generate triggers that provide Earth horizon position information which allow spacecraft attitude to be determined. There are two ES systems; one aimed radially for spin-mode use, the other top mounted for 3-AXIS MODE.

EXPFLAG
Experiment status. If the battery voltage falls below a safe level, experiments are switched off in sequence. EXPFLAG records the condition.

GB
General Beacon. Normal telemetry beacon. See section on Frequencies.

GPS
Global Positioning System. Four antennas/preamps/receivers are connected to a module that interfaces to the RUDAK system. GPS should be able to provide position and velocity data which can be converted into orbital data such as Keplerian elements.

HF
High Frequency. See MON.

HIGAIN
High Gain. All transmitters are equipped with beam antennas giving up to 20 dbi gain, and a beamwidth commensurate with Earth's diameter. See also IR laser.

HP
Heat Pipe. The system of thermal management employed within the spacecraft is based on ammonia filled heat pipes girdling the structure. [Note: this is NOT the ammonia used for the ATOS motor!]

I
abbreviation for electrical "current".

IHU , IHU-1
Integrated Housekeeping Unit. The CDP-1802 flight management computer.

IHU-2
Experimental IHU, based on the Intel/Digital SA-1100 microprocessor. This computer has no executive responsibility, but has its own sensors and a small b/w camera (YACE). IHU-2 can monitor IHU-1 telemetry, and either process it, or simply repeat it. http://www.amsat.org/amsat/articles/g3ruh/124.html

IN
Refers to the CDP-1802 IN instruction, which can read data from up to 8 external hardware devices, using the codes IN 8 to IN F .

IPS
Interpreter for Process Structures. The operating system used in the spacecraft flight computer, IHU-1. Also used in the IHU-2.

IR
Infra Red laser, the optical (~800 nm) communication experiment. Mean power ~250 mw, "antenna gain" ~41 dBi. Carries PSK beacon stream.

K
Ku-band transmitter; frequency ~24 GHz

L1, L2
There are two L-band receivers (23cm), called L1 and L2.

L-BAND
L-band frequency ~1269 MHz (23cm).

LEILA
(LEIstungs Limit Anzeige) Electronic module that can be optionally inserted into a RX - TX path in order to regulate excessively strong signals. There are two Leila units.

LIU
Liquid Ignition Unit. Electronics that controls the 400N rocket motor.

LSB
Least significant bit (or byte).

MA
Mean Anomaly. Number describing spacecraft position around an orbit, starting from 0 at perigee (closest point to Earth), also ending at perigee. See also Z

MATRIX
The spacecraft's many receivers can be coupled to the many transmitters in a fairly free manner. The MATRIX is an array of relays controlled by flight software to do this. The common IF is 10.7 MHz.

MB
The Middle Beacon is used for the IHU-2 telemetry. But if the IHU-2 is powered off, the middle beacon carries normal IHU-1 telemetry. See section on Frequencies.

MMH
Mono-methyl hydrazine. Fuel for the 400N rocket motor. See also N2O4

MON
The ionosphere MONITOR experiment is designed for passive sounding the space above the ionosphere in the HF band between 0.5 and 30 MHz. The analog part of the monitor measures the electromagnetic field density at HF. Data via RUDAK.

MSB
Most significant bit (or byte).

MUX
Multiplexer. Electronics that selects a signal from a large number of sources. See also ADC, 2MUX, 3,4MUX.

N2O4
Nitrogen tetroxide Oxidiser that burns the MMH fuel in the 400N rocket motor.

NH3
Ammonia. Propellant used in the ATOS arc-jet thruster.

OMNI
Omni-directional antenna. AO-40 has these for V, U and L-bands. Used during early phases of mission when orientation may not favour HIGAIN antennas.

OUT
Refers to the CDP-1802 OUT instruction, which can write data to up to 8 external hardware devices, using the codes OUT 0 to OUT 7.

P3
Phase 3 - describes a satellite in an high elliptical orbit (HEO). Phase 2 are satellites in a low earth orbit (LEO). Phase 1 were satellites in a low earth orbit without solar cells, and a very limited lifetime, depending on the battery.

P3D
Phase 3 D. 4th spacecraft of the Amsat Phase 3 series:
P3A was lost with the second test flight of Ariane 1.
P3B was launched on ARIANE L6 and became AMSAT OSCAR-10 (1983-).
P3C was launched on the first ARIANE 4 qualification flight and became AMSAT OSCAR-13 (1988- 96).
P3D was launched 2000 Nov 16 by Ariane V135, and became AMSAT OSCAR-40.

PA
Power amplifier

PLL
Phase Locked Loop. An electronic circuit containing an tunable oscillator that synchronises itself to an incoming periodic signal, such as a pulse or data stream. The SEU Sun and Earth sensor system has one of these.

PREAMP
Preamplifier. L1/L2 receivers, Monitor experiment and GPS have pre-amplifiers at the antenna.

PSK
"Phase Shift Keying". Refers to modulation format used for 400 bps telemetry stream.

PSU
Power Supply Unit. Term embracing regulators, relays, batteries etc.

RUDAK
Digital Communications Equipment for users. Has four 9600 bps FSK downlinks, and two 153,600 bps PSK downlinks, one with optional 7,2 convolutional encoding. Also has 8 DSP uplinks/downlinks for software modems.

RX
Receiver. There are many receivers, connected to a MATRIX controlled by software, to route their signals to any selected TX.

S/A
Safe/Arm plug status. A colour-code plug on the spacecraft enables or disables the 400N rocket motor system and other critical systems. A safety requirement for launch integration; a green plug is Safe; a red plug is Armed for flight. Telemetry indicates which plug is in use. Should be "Arm" after launch.

S/C Spacecraft.

S1 S2
There are two S-band transmitters and two S-band receivers. Frequency 2400 MHz and 2401 MHz.

SA (1)
Solar Array. See SOLPANL

SA (2)
Sun Angle. The angle that the Sun makes to the solar panels or to a specific sun sensor.

SCOPE
Two colour cameras for observing the planets and Earth.

SEU
Sensor Electronic Unit. Electronics that manages the Sun and Earth sensors. Comprises a PLL that synchronises itself to the flashes of sunlight as the spacecraft rotates. This then provides timing for events as seen by the Sun Sensors SS1 , SS2 and Earth sensors ES.

SOLPANL
Solar Panel. There are 6 solar panels. In post-launch, SPIN-MODE these are folded around the spacecraft, bat-style. In 3-AXIS MODE two pairs of hinged panels swing out to make "wings".

SPIN-MODE
After launch the spacecraft will be spin stabilised in this mode. Later stabilisation will be via 3 momentum wheels, called the 3-AXIS MODE.

SS
Sun Sensor. Device for measuring angle of the Sun with respect to its axes. There are sun sensors for SPIN-MODE and for 3-AXIS MODE.

SS1 SS2
Sun Sensor 1 and 2. A pair of optical sensors for SPIN-MODE that together allow Sun angle to be calculated.

SU0, SU1 etc
Stopwatch (Germ.) Location in SYSPAGE where IPS keeps four timers for general purpose use.

SYSPAGE
System Page. Area of flight computer's memory used by IPS as its principal workspace.

T/Z
Name of a software counter used by IPS to pace downlink telemetry blocks.

TDE
Total Dose Experiment is a subsystem of CEDEX. The purpose of the TDE is to measure the accumulated ionising radiation dose inside the PHASE-3D spacecraft.

TLM
Telemetry

TWTA
Travelling Wave Tube Amplifier. High power (50W) amplifier used in X-band transmitter.

TX
Transmitter. There are many of these. See RX .

TXFLAG
Transmitter status. If a transmitter overheats, it is automatically turned off, and the condition recorded in TXFLAG.

U
U-band transmitter or receiver. Frequency ~435 MHz.

U/D
Up and/or Down. Refers to top/bottom of spacecraft.

UHR

Time (Germ.) Location in SYSPAGE where IPS keep the UTC clock.

WHEEL

Three magnetically suspended, heavy wheels spinning at a nominal 3000 rpm can have their speed changed. The change in momentum causes controlled re-orientation of the spacecraft. They are activated in 3-AXIS MODE.

V

V-band transmitter or receiver. Frequency ~146 MHz.

X

X-band transmitter. ~10 GHz.

YACE

"Yet Another Camera Experiment". 512x512 pixel black and white imager attached to IHU-2. Field of view is 20.74 x 20.74 deg. Software can apply JPEG compression to images for download.

YAHU

"Yet Another Housekeeping Unit". See IHU-2.

Z (1).

Coordinate axis; points out of 400N rocket motor. See +X.

Z (2).

Counter(s) in IPS describing position around elliptic orbit. Synonymous with MA as used in orbital mechanics & tracking programs. Z = 256 is equivalent to MA = 360 deg.