The ICA-IMA-VIA TC/TM data formats

and related software aspects.

Issue 1.7

2004-10-28 Hans Borg. IRF- Kiruna.

Document history.

Date	Issue	By	Changes
2002-04-07	Draft	HB	Composed and edited from several partial documents.
2002-04-20	1.2	HB	Added: Related documents. Important NOTE for HK-data change. Corrected standard header status bit.
2002-05-08	1.3	HB	Added: Mass order for table look up. Command status coding.
2003-05-16	1.4	HB	Corrected parameter orders (§5.2.1,§5.2.3) Timing and time tagging. (8.0)
2003-09-07	1.5	HB	Added header (§5.5.1) & HK (§6.1) parameters descriptions. Extra to timing (§8.2)
2004-05-08	1.6	HB	Added VIA specific definitions. Updated some ICA default settings.
2004-10-28	1.7	HB	Parameter order (§5.2.3 and §5.4).

Related documents.

1) ICA – RPC : the Ion Composition Analyser in the Rosetta Plasma Consortium. O Norberg et. al.
Note: “The ICA –RPC: … should basically be applicable on the IMA - MU configuration”

2) ICA command description. Issue 1.5. H Borg.

3) IMA command description. Issue 1.4. H Borg.

4) CCSDS 120.0-B-1.

5) Basics of ICA/IMA embedded software. Issue: 1.3 H Borg

6) ICMA_ADC_CAL_yymmdd.doc (Current: yymmdd=030910 by HB)

Table of contents.

1.0 Scope.

As the ICA (RPC/Rosetta), the IMA (Aspera/Mars Express) and VIA (Aspera/Venus Express) experiments are essentially the same this document treats all three. Differences are explicitly noted. It only briefly describes the operation of the experiments.
It is assumed that the reader has a basic knowledge of the experiments.

The document tries to describe in some detail the tm data return from the experiments.

2.0 Terminology.

If not otherwise stated a byte denotes an 8-bit item and a word a 16-bit item. A nibble is a 4-bit item. Bits are labeled in the power of 2, i.e. 0 (zero) is the least significant bit.
Precaution: ESA uses “octets” for an 8-bit item and “word” for a 16-bit item. ESA also uses 0 as the MS-bit (Mil Std. 1750 convention. Item size dependent).
F8 denotes an experiment 8-bit hybrid floating code used to reduce 32/16 bit parameters to 8 bits.

3.0 Experiment basic operation.

The basic operation consists of stepping through 32 or 96 energy HV deflection steps for each of 16 entrance HV deflection steps (polar angles). A complete cycle (scan) takes 64 seconds (32 levels) or 192 seconds (96 levels) respectively. The sampling time is 102.9 milliseconds. Each sample produces an imager matrix of 32 mass bins times 16 sectors (azimuth angles).

The data acquisition and transmission is synchronized to an acquisition (start) pulse. For ICA that pulse is received once per 32 seconds and for IMA once per 16 seconds.

All data to and from the experiment is transmitted over a serial 1355-link from/to a central unit that in turn interfaces to the spacecraft systems.

Each format starts with a 16-byte long standard header with a 3-byte long synchronization pattern.

Except for the header and some data in the special modes all data is by default converted to an 8-bit hybrid floating code (F8) followed by a loss less bit data compression.
Thus, most ICA-IMA data formats will float in the ESA telemetry packets. Some may, however, be synchronized (see §5.4).

For a more detailed description of the experiment see ICA – RPC : the Ion Composition Analyser in the Rosetta Plasma Consortium. (Norberg,O. et al.).

4.0 The commanding system.

4.1 General

With a few exceptions all experiment commands consists of a 16-bit word.
The word is subdivided into 4 nibbles n3-n0.

n3	**n2**	**n1**	**n0**

The commands are divided into 3(4) classes (types) as:

Type 3 n3 ∴ 0 n2,n1,n0 represents a 12-bit variable parameter.
Capacity: 15 sets. n3=1-15.

Type 2 n3=0 n2∴0 n1,n0 represents an 8-bit variable parameter.
Capacity: 15 sets. n2=1-15.

Type 1/0 n3=n2=0 n1,n0 is dynamically used for variable length parameters like 4-bit, 1-bit or no parameter commands.
Capacity: 256 sets. n1,n0=0-255.

Note: The combined command words = 0xFFFF or 0x0000 are not used for safety.

The basic experiment internal interpretation of the 16-bit word is given below (§4.2).

For further details about commanding, see ICA/IMA Command Description. Issue 1.4. (H Borg).

4.2 Detailed command list.

The list below gives all the commands in terms of a short description, type, fixed part, parameter mask, acceptable parameter range and when applicable the default value. Note that this is the internal interpretation.

Prm: below stands for parameter. A "-" below indicates not applicable or not defined.

Short description	Type	Fixed part	Prm. mask	Prm. range	Default
Main +28 volt switch	1/0	0x0002	0x0001	0-1	0
Opto +28 volt switch	1/0	0x0004	0x0001	0-1	0
Mcp +28 volt switch	1/0	0x0006	0x0001	0-1	0
Post acc. HV switch	1/0	0x0008	0x0001	0-1	1
Grid LV switch	1/0	0x000A	0x0001	0-1	1
Entrance HV switch	1/0	0x000C	0x0001	0-1	1
Deflection LV switch	1/0	0x000E	0x0001	0-1	1
Deflection HV switch	1/0	0x0010	0x0001	0-1	1
Direct command switch	1/0	0x0012	0x0001	0-1	0
Watch dog enable/disable	1/0	0x0014	0x0001	0-1	1
Gas pressure HV control. **ICAonly**	1/0	0x0016	0x0001	0-1	0
Thruster firing HV control. **ICA only**	1/0	0x0018	0x0001	0-1	0
Compression enable/disable	1/0	0x001C	0x0001	0-1	1
Alternating post acc. enb/dis	1/0	0x001E	0x0001	0-1	0
Post acc. level high/low	1/0	0x0020	0x0001	0-1	1
Auto reduction change enb/dis	1/0	0x0022	0x0001	0-1	1
Shadow masking enb/dis	1/0	0x0024	0x0001	0-1	1
Bad HV masking enb/dis	1/0	0x0026	0x0001	0-1	1
Bad mass clearing enb/dis. **VIA only**	1/0	0x0028	0x0001	0-1	0
Next command direct	1/0	0x0040	-	-	-
Energy deflection stepping	1/0	0x0041	-	-	-
Entrance deflection stepping	1/0	0x0042	-	-	-
Release V-cal format	1/0	0x0043	-	-	-
Activate debugger. Bench only	1/0	0x0046	-	-	-
Gas-HV timeout test. **ICA only**	1/0	0x0047	-	-	-
Trigger machine error. Bench only	1/0	0x0048	-	-	-
Test Watch dog reset.	1/0	0x004A	-	-	-
Empty TM fifo	1/0	0x004B	-	-	-
Flush TM fifo	1/0	0x004C	-	-	-
Boot PROM	1/0	0x004D	-	-	-
Imager test	1/0	0x004E	-	-	-
Dummy command	1/0	0x004F	-	-	-
Set HV ref. Range bits. **VIA only.**	1/0	0x0050	0x0003	0-3	-
Set bad mass index bit MS. **VIA only**	1/0	0x0060	+ 2:nd wrd	0-0xFFFF	0
Set bad mass index bit LS. **VIA only**	1/0	0x0070	+ 2:nd wrd	0-0xFFFF	0
Boot EEPROM incl. Context	1/0	0x00B0	0x000F	0-15	-
Set imager test pattern	1/0	0x00C0	0x000F	0-15	-
Boot EEPROM excl. Context	1/0	0x00D0	0x000F	0-15	-
Set **ICA/IMA-VIA** SID number	1/0	0x00E0	0x000F	0-5/0-6	5
Set EEPROM default boot section	1/0	0x00F0	0x000F	0-15	0

Short description	Type	Fixed part	Prm. mask	Prm. Range	Default
Set energy deflection level	2	0x0100	0x00FF	0-95	-
Set entrance deflection level	2	0x0200	0x00FF	0-15	-
Set **ICA/IMA/VIA** solar wind start index	2	0x0300	0x00FF	0-64	29/24/22
Set Gas pressure low level. **ICA only**	2	0x0400	0x00FF	0-255	0x16
Set Gas pressure high level. **ICA only**	2	0x0500	0x00FF	0-255	0x15
Set data reduction mode	2	0x0A00	0x00FF	0-39	0
Reprog. all EEPROM sections *)	2	0x0C00	0x00FF	0-16	-
Reprog. EEPROM section *)	2	0x0D00	0x00FF	0-255	-
Set **ICA/IMA/VIA** Opto reference	3	0x1000	0x0FFF	0-7	7/6/6
Set **ICA/IMA/VIA** Mcp reference	3	0x2000	0x0FFF	0-15	12/13/12
Set **ICA/IMA** Grid reference	3	0x3000	0x0FFF	0-7	7/7
Set **ICA/IMA/VIA** post acc. low reference	3	0x4000	0x0FFF	0-7	3/4/3
Set **ICA/IMA/VIA** post acc. hgh reference	3	0x5000	0x0FFF	0-7	6/7/6
Set energy defl. LV reference	3	0x6000	0x0FFF	0-4095	-
Set energy defl. HV reference	3	0x7000	0x0FFF	0-4095	-
Set entrance defl. HV reference	3	0x8000	0x0FFF	0-4095	-
Set noise reduction level	3	0x9000	0x0FFF	0-4095	0
Set **ICA/IMA-VIA** Fifo low (min) water mark	3	0xA000	0x0FFF	0-4095	40/20
Set **ICA/IMA-VIA** Fifo high (max) water mark	3	0xB000	0x0FFF	0-4095	80/40
Set **ICA/IMA-VIA** Fifo force water mark	3	0xC000	0x0FFF	0-4095	120/60
Set **ICA/IMA-VIA** Fifo clear water mark	3	0xD000	0x0FFF	0-4095	320/320
Set IMA Tm scaling factor. **IMA-VIA only**	3	0xE000	0x0FFF	0-4095	180
Start command (combined)	3	0xF000	0x0FFF	0-4095	-

*) Requires a second word reading 0xFEED (security lock key).

5.0 Telemetry/Science modes.

5.1 Telemetry modes.
The experiments have to their disposal a number of telemetry modes (here named Sid, Science ID). The Sid defines the TM rate available. The Sid numbers below are the internal ICA-IMA numbers that is also used in commanding. Note that direct (near real time) TM is mostly not available. The TM data is buffered onboard the S/C. The TM rate below then describes the reasonable amount to create to stay within the buffer allowance allocated for the planned S/C session before tapping to a ground S/C tracking station.

Telemetry modes (Sid+HK).

Sid	Mnemonic	Exp. Pkt. size in bytes	ICA rate	IMA rate
0	Min (Minimum)	618	5.15 bps	10.3 bps
1	Nrm (Normal)	2478	103.25 bps	206.5 bps
2	Bst (Burst)	4092	1023 bps	2046 bps
3	Cal (Calibration)	1074	268.5 bps	537 bps
4	Spc (Special)	3198	799.5 bps	1599 bps
5	Tst (Test)	600	75 bps	150 bps
6	Ima (Ima)	3996 *	NA	3996 bps
HK	Housekeeping	24	6 bps	12 bps

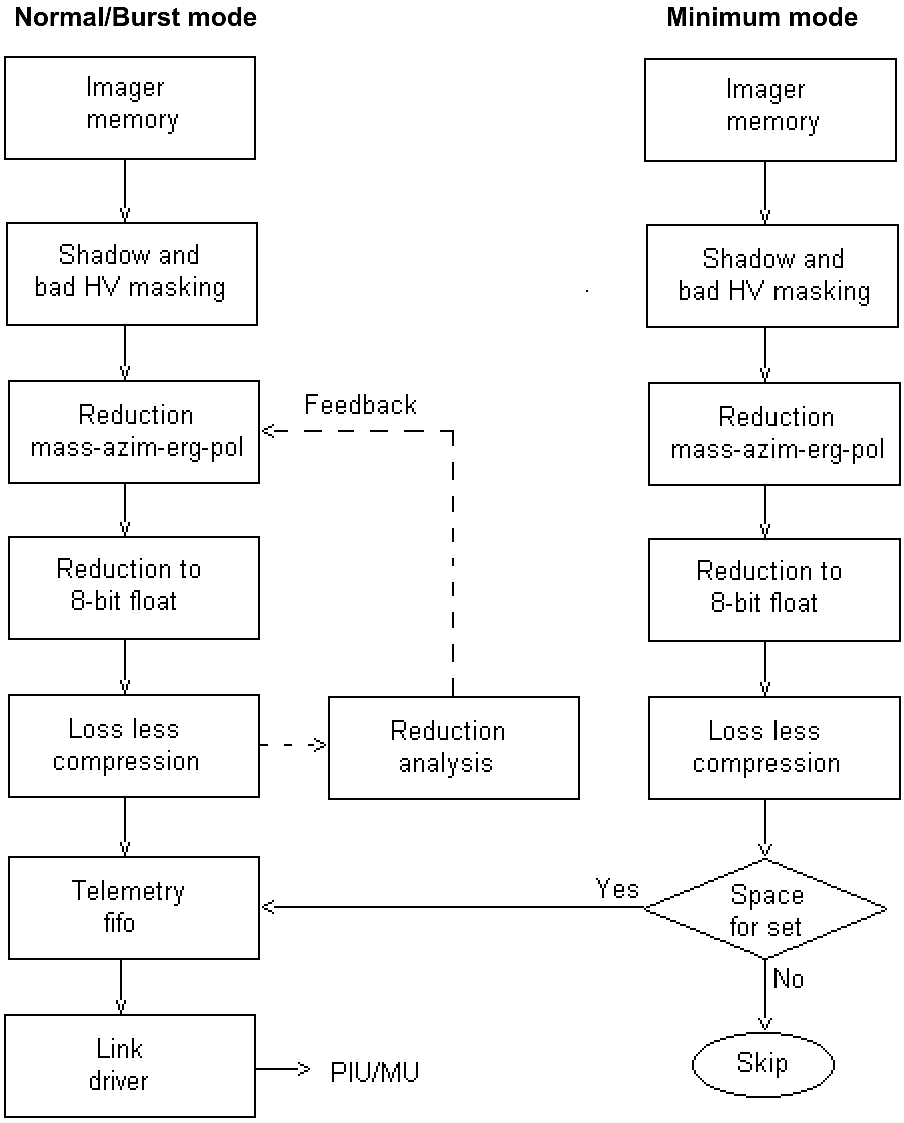
*) For IMA-VIA 2 such packets are sent every acquisition period.

5.2 Data reduction modes general.
The H/W operation of the experiment is always the same but for the 32 or 96 energy level step modes. The number of energy levels is strictly tied to the science mode selected. The experiment produces too much data to be transmitted (~ 80 000 bps). The parametric space measured are 32 mass bins (not true M/q) for 16 azimuths, 16 polar angles and 96 (32) energy levels. To cope with the high production rate versus the available Tm rate capacity the data is first reduced by integrations in the measured parametric space. The resulting (32/16 bit parameters) are then converted to a hybrid 8 bit floating code (F8). The size of the data set (format) is after this mostly still too big. The data therefore passed via a loss less bit compression routine before feeding it to the tm output FIFO.

The tm FIFO can take a certain backlog of data due to its size. The backlog is watched by low and high watermarks. When appropriate, the S/W will change the reduction scheme such as to stay (on average) within the allocated tm rate. Thus the watermarks are scaled against the current telemetry mode. A more detailed description is given in § 5.2.1

5.2.1 Science data processing.
The data is read from the imager memory, shadow masked and fed to a data reduction module. The reduction is performed by integrations in the parametric space azimuth*mass*energy*polar-angles. When a full data set is acquired a 32/16 bit to a hybrid 8 bit floating code further reduces the data. The resulting data set is then compressed by a loss less method and fed to the telemetry FIFO for transmission. The TM-FIFO can take a certain backlog with respect to the current TM-rate (SID). The size of the compressed data will vary due to the characteristics of the actual data. For the *Normal* and *Burst* modes the TM-FIFO filling is controlled by analyzing the data set size with respect to the TM-FIFO filling and the actual TM-rate. When appropriate, a feedback is made to the reduction module to change the reduction scheme. The TM-FIFO filling is guided by watermarks. For the *Minimum* modes that create several data sets during the duration of a format, the reduction is fixed but instead the number of sets to transmit is adjusted to match, on the average, the TM-rate (SID).
The automatic data reduction change and data compression can be disabled by commands. It affects both *Minimu*m and *Normal/Burst* modes.

Principle data flow.



5.2.2 Shadow and bad HV masking.
It is just the fact that the anticipated field of view of the experiments is not clean. Due to the mounting there are other S/C obstacles in the field of view. The current S/W has built in tables to simply clear out (set to 0) imager sectors that are more or less obscured. This has a two-folded motivation.

a) A clear knowledge of what data is included (partly obscured may give “funny” effects).
b) Zeroing out may (not for sure) give a better compression efficiency.

Like wise, due to HV limitations (capacity or accuracy) all polar angles cannot be reached for all energies. They are treated as for shadowed sectors above.

5.2.3 Parameter orders.
Apart from the Special modes (5.4), Science data are always delivered as a matrix azimuth*mass*energy*polar, where azimuth (the first) is the fastest varying one.
For masses above or equal to 8, the integration is simply done by adding adjacent mass bins. E.g. 8 mass bins integrate them 4 by 4 from the 32 available.
Note that the Imager addressing is such that the heavier masses comes first and the lighter ones last.
For masses below 8 (i.e.<= 6), the mass bins are integrated according to lookup tables and supposed to represent true M/q. The transmission order of the M/q masses is defined by the lookup tables.
The mass order for ICA and IMA is: H+ >O+ O+ He+ He++ O++
and for VIA: H+ O+ He+ >O+ He++ O++
If less than 6 masses, masses at the end are skipped.

Azimuth, energy and polar angles always come in the same order.

5.3 The data modes.
The data modes are divided into 5 groups: Min, Nrm, Har, Exm and Special.

5.3.1 The minimum modes.
The duration of the Minimum mode data formats is 16 minutes.

Mode	Index	Masses	Azimuth angles	Energies	Polar angles	Max sets
Idle *	0					
Void	1					
Mspo	2	2	1	32	1	15
Void	3					
Msis	4	6	1	96	1	5
Mexm	5	32	1	96	1	5
Void	6					
Void	7					

*) The Idle mode produces no scientific data and is described under the Special modes.

5.3.1.1 Minimum spectra only (Mspo).
The energy deflection is stepped through 32 levels starting at the solar wind start index.
For each scan all data for the two masses protons and alpha (table look up) are integrated over the sunward facing sectors. This produces a maximum of 15 sets of 2 masses * 32 E-levels spectra. As many as can be fitted (on the average to stay within the TM capacity) in the current SID block size are transmitted.

Layout: 1 header
n 2*32 spectra (Compressed F8)

5.3.1.2 Minimum selected ion species (Msis).
The energy deflection is stepped through all 96 levels for each of the 16 entrance steps.

For each scan all data for 6 selected ion species (table look up) are integrated over all angles (azimuth and polar). This produces a maximum of 5 sets of 6 masses * 96 E-levels spectra. As many as can be fitted (on the average to stay within the TM capacity) in the current SID block size are transmitted.

Layout: 1 header
n 6*96 spectra (Compressed F8)

5.3.1.3 Minimum energy-mass matrix (Mexm).
The energy deflection is stepped through all 96 levels for each of the 16 entrance steps.

For each scan all data for 32 mass bins are integrated over all angles (azimuth and polar). This produces a maximum of 5 sets of 32 mass-bins * 96 E-levels spectra. As many as can be fitted (on the average to stay within the TM capacity) in the current SID block size are transmitted**.**

Layout: 1 header
n 32*96 spectra (Compressed F8)

5.3.2 The normal modes (Nrm).
The duration of the Normal mode format is 192 seconds.
The energy deflection is stepped through all 96 steps for each of the 16 entrance steps.

The normal mode (group) is subjected to an automatic change of the data reduction scheme (if enabled) in order to adapt to the current TM capacity (SID).
The order of the reduced data matrix is always Mass-Azimuth-Energy-Polar with Mass being the fastest varying index. The masses are integrated by means of energy dependent lookup tables.

The reduction scheme.

Mode	Index	Masses	Azimuth angles	Energies	Polar angles
Nrm-0	8	6	16	96	16
Nrm-1	9	6	16	96	8
Nrm-2	10	6	16	96	4
Nrm-3	11	6	16	96	2
Nrm-4	12	6	8	96	2
Nrm-5	13	6	4	96	2
Nrm-6	14	3	4	96	2
Nrm-7	15	3	4	96	1

Layout: 1 header
1 data set (Compressed F8)

5.3.3 The burst high angular resolution modes (Har).
The duration of the burst high angular resolution mode format is 192 seconds.
The energy deflection is stepped through all 96 steps for each of the 16 entrance steps.

The burst high angular resolution mode (group) is subjected to an automatic change of the data reduction scheme (if enabled) in order to adapt to the current TM capacity (SID).
The order of the reduced data matrix is always Mass-Azimuth-Energy-Polar with Mass being the fastest varying index.

The reduction scheme.

Mode	Index	Masses	Azimuth angles	Energies	Polar angles
Har-0	16	16	16	96	16
Har-1	17	16	16	96	8
Har-2	18	16	16	96	4
Har-3	19	8	16	96	4
Har-4	20	4	16	96	4
Har-5	21	2	16	96	4
Har-6	22	2	8	96	4
Har-7	23	2	8	96	2

Layout: 1 header
1 data set (Compressed F8)

5.3.4 The burst energy-mass matrix modes (Exm).
The duration of the burst energy-mass matrix mode format is 192 seconds.
The energy deflection is stepped through all 96 steps for each of the 16 entrance steps.

The burst energy-mass matrix mode (group) is subjected to an automatic change of the data reduction scheme (if enabled) in order to adapt to the current TM capacity (SID).
The order of the reduced data matrix is always Mass-Azimuth-Energy-Polar with Mass being the fastest varying index.

The reduction scheme.

Mode	Index	Masses	Azimuth angles	Energies	Polar angles
Exm-0	24	32	16	96	16
Exm-1	25	32	16	96	8
Exm-2	26	32	16	96	4
Exm-3	27	32	16	96	2
Exm-4	28	32	8	96	2
Exm-5	29	32	4	96	2
Exm-6	30	32	2	96	2
Exm-7	31	32	2	96	1

Layout: 1 header
1 data set (Compressed F8)

5.4 The special modes.
The special modes are mainly aimed for ground testing and calibration, but may well be used also when in orbit. Typically "Test" for commissioning.
As opposed to the science modes, the special modes do not allow any Tm FIFO backlogging.
The Test and the Cal1 mode will be synchronized to the ESA packets provided they run in combination with the Telemetry modes Tst and Cal respectively. The Fake mode is always synchronized to the ESA packets.
The order of the imager data transmitted are of type imager dump (snap shot), i.e. in the order as seen from the imager memory.
For Test,Cal1 modes that is mass*azimuth and for Cal2 mass*azimuth*energy.

Mode	Index	Content
Test	32	H/W close information and an Imager snapshot
Cal1	33	HV information and one Imager in 16-bit uncompressed words
Cal2	34	HV information and 96 Imagers (one per Energy level) in compressed F8
Fake	35	An incremental (by one) 16-bit counter in 16-bit uncompressed words
Void	36	
Void	37	
Void	38	
Void	39	

5.4.1 The test mode (Test).

The test mode delivers “hard ware close” information and do not contain any compressed data. It is 600 bytes long and will be synchronized to the ESA TM packets if SID=Tst (ICA-IMA nr 5) is used.

It contains the following data:

Byte offset	Length in bytes	Bits	Content
0	16		Standard header. See §5.4.6
16	2		Command word 0 return
18	2		Command word 1 return
20	20		10 16-bit AD monitor values. See &5.4.7
40	1		Void
41	1		Nos. 1355-link forced resets
42	1		Nos. 1355-link resets seen
43	1		Nos. 1355-link credit failures
44	2	 15-10 9-8 7-4 3-0	EEPROM programming result Reprogramming counter Failure bits Destination EEP section Source EEP section
46	1		Nos. Watch dog resets
47	1		Nos. machine error resets
48	1		Void
49	3		48-bits S/W switch status. See §5.4.8
52	1		Noise reduction level
53	1		The gas pressure as seen from ROSINA. **ICA only**
54	2	 15 14-12 11-0	Copy from HK format Direct command switch Pacc. low reference level Energy deflection HV reference
56	2	 15 14-12 11-0	Copy from HK format Tm overflow flag Pacc. high reference level Energy deflection LV reference
58	2	 15 14-12 11-0	Copy from HK format Pacc. current level (high=1 or low=0). Grid LV reference Entrance HV reference
60	2		CPU fault register
62	2		CPU fault address
64	1		Gas pressure low level. **ICA only**
65	1		Gas pressure high level. **ICA only**
66	2		CPU BIT result
68	2		Current program version running
70	1		Nos. sample overruns
71	1		Nos. sweep overruns
72	1		Nos. post overruns
73	1		Void
74	2		+28V monitor.
76	2		Fifo low water mark (Fmin)
78	2		Fifo high water mark (Fmax)
80	2		Fifo force limit (Ffrc)
82	2		Fifo clear limit (Fclr)
84	2		IMA Tm scaling factor. **IMA-VIA only**
86	1	 7-6 5-3 2-0	Image memory test result Test counter. Memory half 1 test result Memory half 0 test result
87	1		E-level for Image snapshot
88	512		Imager snapshot in F8 code

5.4.2 The calibration-1 mode (Cal1).

The calibration-1 mode is specially designed for Imager calibration. It is 1074 bytes long and will be synchronized to the ESA TM packets if SID=Cal (ICA-IMA nr 3) is used.

Byte offset	Length in bytes	Bits	Content
0	16		Standard header. See §5.4.6
16	2		The digital deflection HV reference
18	2		The digital deflection LV reference
20	2		The digital entrance HV reference
22	1	7-4 3-0	The Opto. HV digital reference The Mcp. HV digital reference
23	1	7-4 3-0	The digital Post acc. HV reference The Grid LV digital reference
24	20		10 16-bit AD monitors. See §5.4.7
44	2		+28V monitor
46	1		Entrance angle index
47	1		Energy level index
48	2		Void
50	1024		Full Imager in 16-bit words

5.4.3 The calibration-2 mode (Cal2).

The calibration-2 mode is specially designed for Imager calibration. It delivers Imagers for a full 96 E-level sweep. The data is in compressed F8 code.

Byte offset	Length in bytes	Bits	Content
0	16		Standard header. See §5.4.6
16	2		The digital deflection HV reference
18	2		The digital deflection LV reference
20	2		The digital entrance HV reference
22	1	7-4 3-0	The Opto. HV digital reference The Mcp. HV digital reference
23	1	7-4 3-0	The digital Post acc. HV reference The Grid LV digital reference
24	20		10 16-bit AD monitors. See §5.4.7
44	2		+28V monitor
46	1		Entrance angle index
47	1		Energy level index
48	2		Void
50	nn		96 energy levels of full Imager in compressed F8

5.4.4 The faked data mode (Fake).

The Fake mode is specially designed to test the 1355-link for transmissions from the experiment to the PIU/MAIN-unit. It simply delivers a header followed by a word sequential counter as uncompressed data. It automatically adjusts the data size to match the current SID and will therefore always be synchronized to the ESA TM packets. Except for the header missing data can easily be detected.

Layout: 1 header.
An incremental counter to fill the current Sid packet.

5.4.5 The Idle mode.
The mode index refers it to the Minimum group, but may as well be regarded as a special mode. This mode does not produce any science data.

The Idle mode may be entered in two ways.

1) By command.
If entered by command the Opto and Mcp HV are regulated down to 0 reference, but the +28V Main switch stays ON. Also all science tm output are inhibited. Data in the tm FIFO are kept for later transmission. Commanding the experiment into the idle mode opens up for memory management activities (patch, dump or check).

2) Automatic (**ICA only**).
The experiment will enter Idle mode if the gas pressure as delivered by ROSINA excides a predefined upper limit or the experiment receives a thruster fire warning. When entered this way the +28V main switch to the HV supplies is switched off. Data in the tm FIFO, however, will continue to be transmitted.

5.4.6 The 16-bit AD monitors.

The AD monitors are stored in the following order.

Byte offset	Length in bytes	Content
0	2	Opto. HV
2	2	Mcp. HV
4	2	Upper entrance HV
6	2	Lower entrance HV
8	2	Post acceleration HV
10	2	Energy deflection HV
12	2	Energy deflection LV
14	2	Sensor unit temperature
16	2	Grid LV
18	2	DPU temperature

Actual calibration constants will be specified in the ICMA_ADC_CAL document.

5.4.7 The switch status bits.

The switch bits are coded as 0=Off and 1=On.

Bit	Content	Type
0	Mcp. +28V	H/W
1	Opto. +28V	H/W
2	Main +28V	H/W
3	Post acceleration HV	S/W
4	Grid LV	S/W
5	Entrance HV	S/W
6	Energy deflection LV	S/W
7	Energy deflection HV	S/W
8	Direct command	S/W
9	Watchdog	H/W
10	Gas HV control	S/W **ICA only**
11	Thruster firing HV control	S/W **ICA only**
12	Void	
13	Compression	S/W
14	Alternating post acceleration	S/W
15	Post acceleration level	S/W. Not really a switch
16	Auto reduction changes	S/W
17	Shadow masking	S/W
18	Bad HV masking	S/W
19	Void	
20	Void	
21	Void	
22	Test flag	S/W
23	Internal. Not commandable	

5.5 The standard header.
Each data format starts with a standard header containing the following information

Byte offset	Length in bytes	Bits	Content
0	3		Sync. Pattern. 0xE3 0x31 0xCA
3	1	7-6 5-0	Unit (1=ICA 2=IMA) Mode (index)
4	1		Experiment data format counter (Edf)
5	1	7 6 5 4 3-0	HV ramping in progress Tm Fifo emptied Checksum 0 failure Checksum 1 failure Number of sets in Minimum modes
6	1	7 6 5 4 3-0	Compression switch Auto reduction change switch Alternating post acceleration switch Post acceleration level Test pattern
7	1		Fifo filling. Number of 3-wrd packets in F8
8	1	7 6 5 4-0	Post processing overrun Sweep processing overrun Sample processing overrun PROM(0)/EEPROM section(1-16) loaded
9	1	7 6-0	Reset due to Watchdog or Machine error. Solar wind energy start index
10	3		Format start time in units of 31.25 msec. *
13	1	7 6 5-4	Bad HV masking switch Shadow masking switch The mass lookup table nr. VIA only
13	3	19-0	Format length in words

*) As the Format start time only consists of 24 bits, the MSB part should be taken from the ESA packet time. The 24 bits covers about 6 days.

5.5.1 Header parameters description.

Sync. Pattern.
The 3 bytes 0xE3 0x31 0xCA marks the start of a new EDF (Experiment Data Format). A search for this is required as the EDF's floats in the tm data stream.

Unit.
This parameter (2 bits) defines the experiment unit as follows:

0 Undefined
1 ICA
2 IMA
3 VIA

Mode.
This is the data reduction mode index used for the data in this EDF. The corresponding mode acronyms are given in &5.3 and §5.4.

Experiment data format counter.
This is an 8-bit running counter incremented by 1 for each released EDF. It swaps over to 0 after 255.

HV ramping in progress.
This bit will set if HV ramping has been performed during the data taking for this EDF.

Tm Fifo emptied.
This bit will set if the tm fifo is emptied before the start of this EDF. Always forced to and from special EDF's

Checksum 0,1 failures.
These bits will set if the corresponding checksum (0 or 1) fails during RAM booting. Sets from both PROM and EEPROM booting.

Number of sets in Minimum modes.
This parameter (4 bits) gives the number of data sets in this EDF for the minimum modes.

Compression switch.
This bit indicates whether data compression is enabled or not. 0=Disabled 1=Enabled.

Auto reduction change switch.
This bit indicates whether automatic data reduction change is enabled or not. 0=Disabled 1=Enabled.

Alternating post acceleration switch.
This bit indicates the post acceleration mode. If set (1) it is alternating else it is fixed.

Post acceleration level.
This bit gives the post acceleration level used for this format. 0=Low 1=High.

Test pattern.
For testing purposes a number of imager test patterns can be commanded. This parameter (4 bits) gives the actual test pattern number used. Ensure it is 0 for real scientific data.

Fifo filling
This gives the approximate number of 1355 link packets in the tm fifo. To convert to words, unpack the F8 code and multiply by 3.

Post,Sweep,Sample processing overrun.
These bits are set if a process overruns, i.e. the current data processing is not finished when a new is requested.

PROM(0)/EEPROM(1-16) loaded.
This parameter (5 bits) gives the program code currently loaded and running in RAM. It is coded as: 0=PROM   1-16=EEPROM section 0-15.

Reset due to Watchdog or Machine error.
This bit will set if the experiment has rebooted due to a watchdog or machine error reset.

Solar wind energy start index.
This parameter (7 bits) gives the energy start index when in the 32 level energy mode.

Format start time in units of 31.25 msec.
These 3 bytes is the starting time of this EDF. Note that more significant bits must be taken from the ESA packet time. Some attention should be paid close in time when this 3 bytes counter swaps around. That happens at about once per 6 days.

Bad HV masking switch.
This bit indicates if imager data is masked (set to zero) or not for angles/energies that can not be reached due to insufficient or too inaccurate HV. 0=Disabled   1=Enabled.

Shadow masking switch.
This bit indicates if imager data is masked (set to zero) or not for angles that are regarded as obscured by other S/C items. 0=Disabled   1=Enabled.

Mass lookup table nr.
This nr (0-2) indicates the actual mass lookup table used for this format.

Format length in words.
This parameter (20 bits) gives the total length of the format (EDF) in words.

5.6 Telemetry/Data reduction mode combinations.
In principle any Data reduction mode can be combined with any Telemetry mode. All combinations will, however, not optimize the use of the telemetry capacity. There are no precautions or restrictions built into the S/W to refuse some combinations. In the worst case (like a burst mode in the Minimum Sid) no science data at all will be delivered due to Tm FIFO clearing, provided the Auto reduction change is enabled.
The table below gives the anticipated combinations. Other combinations may, however, be used as a result of experiences from in orbit operation. Likewise the Fifo controlling limits may be trimmed.

Telemetry mode	**Data reduction modes**
Minimum (0)	Minimum modes
Normal (1)	Normal modes
Burst (2)	Burst modes (Har, Exm)
Calibration (3)	Calibration 1. Tailored
Special (4)	Calibration 2
Test (5)	Test. Tailored
Ima (6). IMA only	Burst modes (Har, Exm)

The Fake and Idle modes are applicable in all Telemetry modes.

6.0 The Housekeeping format.
The housekeeping format consists of 24 bytes delivered once per acquisition period. This rate is independent of the current Telemetry mode (Sid) in effect.
The ICA-IMA housekeeping format contains the following parameters:

Byte offset	**Length in bytes**	**Bits**	**Content**
0	1	7-2 1-0	Current data reduction mode. For index see §5.3 & 5.4 Last command status where: 0=Ok 1=Parameter out of range 2=Invalid 3=Erroneous opcode
1	1		HV switch status. The first 8 switches. See §5.4.7
2	1	7 6-4 3 2 1 0	The new command received toggle bit The current Sid number Post acceleration mode (Fixed/Alternating). +28V Main HV present * +28V Opto HV present * +28V Mcp HV present *
3	1		Fifo filling in terms of internal packets (words/3) in F8
4	2		The first word command return.
6	1		The Opto. HV monitor
7	1		The Mcp. HV monitor
8	1		The Energy deflection HV monitor
9	1		The Energy deflection LV monitor
10	1		The Post acceleration HV monitor
11	1		The Grid LV monitor
12	1		The Sensor unit temperature
13	1		The DPU Temperature
14	2	15 14-12 11-0	The direct command switch Post acceleration low level reference Energy deflection HV reference
16	2	15 14-12 11-0	Tm Fifo overflow Post acceleration high level reference Energy deflection LV reference
18	2	15 14-12 13	Post acceleration level (high or low) Grid LV reference. ICA-IMA only. The Dfl. HV range bit. VIA only.

		12 11-0	The Ent. HV range bit. VIA only. Entrance HV reference
20	2	15-13 12-9 8-0	Opto. HV default reference Mcp. HV default reference Entrance upper HV monitor
22	2	15-13 12-9 8-0	Opto. HV current reference Mcp. HV current reference Entrance lower HV monitor

*) For an explanation of the present status, See ICA/IMA Command Description Issue 1.4.

The monitor calibration constants will be specified in the ICMA_ADC_CAL document.

Important NOTE. Byte 2, bit 3 was intended to be the HV safety plug status (HV enabled/disabled). This status had to be taken out for technical reasons. The bit is now used to indicate the post acceleration mode of operation (Fixed or Alternating).

6.1 HK parameters description.

<u>Current data reduction mode.</u>
This gives the data reduction mode index (6 bits) currently running. The corresponding mode acronyms are given in &5.3 and 5.4.

<u>Last command status.</u>
This parameter (2 bits) gives the status of the last received command. The coding is

0=Ok	1=Parameter out of range
2=Invalid in current context	3=Erroneous opcode

<u>HV switch status.</u>
This gives the status of the HV switches (the first 8 from the switch register), where 0=Off and 1=On. The bit and switch relations are given in §5.4.7

<u>New command received toggle bit.</u>
This bit will toggle 0/1 each time a new command is received and the command status and the command return is fed to the HK transmit buffer.

<u>The current Sid number.</u>
This parameter (3 bits) gives the currently used Sid (tm mode). The acronyms and average bit rates are given in §5.1

<u>Post acceleration mode.</u>
By default, the post acceleration runs on a fixed HV setting. In can, however, be commanded to alternate between the preset high and low level HV. This bit is encoded as 0=Fixed, 1=Alternating.

<u>+28V Main,Opto,Mcp HV present.</u>
These 3 bits indicates the actual presence of the +28V after respective switch. 0=No and 1=Yes. See §6.0 for the bit switch-relations.

<u>Fifo filling in terms of internal packets.</u>
This gives the approximate number of 1355 link packets in the tm fifo. To convert to words, unpack the F8 code and multiply by 3. For F8 code, see § 7.0.

<u>The first word command return.</u>
This holds the first word (16 bits) of the last command received.

<u>The HV,LV and temperature monitors at offsets 6-13.</u>
These are 8-bit unsigned ADC readings for HV,LV and temperature monitors. Calibration factors will determine the sign. See §6.0 for the relation between offset and corresponding monitor.

<u>The direct command switch.</u>
ICA/IMA commands are of two types, direct or synchronized. The synchronized ones are executed at the end of format only. Setting the direct command switch ON (1) will turn synchronized commands to be direct.

<u>Post acceleration low level reference.</u>
This is the default digital low level post acceleration reference (3 bits).

<u>Energy deflection HV reference.</u>
This is the digital HV reference value associated with the monitor reading in this format (12 bits).

<u>Tm Fifo overflow.</u>
This bit is set to one if a tm fifo overflow has occurred. That is 0=No overflow 1=Overflow.

<u>Post acceleration level.</u>
This bit indicates the current post acceleration level. 0=Low 1=High.

Energy deflection LV reference.
This is the digital LV reference value associated with the monitor reading in this format (12 bits).

Grid LV reference (ICA-IMA only).
This is the digital grid LV reference value associated with the monitor reading in this format (3 bits).

The Dfl. And Ent. Range bits (VIA only).
This gives the HV range bit settings at the time of the monitor sampling.

Entrance HV reference.
This is the digital HV reference value associated with the monitor reading in this format (12 bits).

Opto. HV default reference.
This is the default digital Opto. HV reference value. That is the target value for ramping (3 bits).

Mcp. HV default reference.
This is the default digital Mcp. HV reference value. That is the target value for ramping (3 bits).

Entrance upper HV monitor.
This is a 9-bit unsigned ADC reading for the upper entrance HV monitor. Calibration factors will determine the sign.

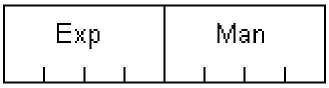
Opto. HV current reference.
This is the current digital Opto. HV reference value associated with the monitor reading in this format (3 bits).

Mcp. HV current reference.
This is the current digital Mcp. HV reference value associated with the monitor reading in this format (3 bits).

Entrance lower HV monitor.
This is an 9-bit unsigned ADC reading for the lower entrance HV monitor. Calibration factors will determine the sign.

7.0 Special data characteristics.
The experiment uses some special tools to handle data. They are briefly described below.

7.1 The F8 code.
In order to reduce the number of bits to transmit, the S/W normally converts 32/16 bit items into a hybrid 8-bit floating code. The maximum capacity is numbers up to 507903. If greater (32-bits only) the number is set to the maximum. It is regarded as a hybrid due to the fact that numbers less or equal to 32 are transmitted as integers. The layout is:



where Exp is the Exponent and Man the Mantissa. Numbers less or equal to 32 are used as is, that is they will be coded as 0x00 – 0x20. If greater the real mantissa part will be used with the MSB stripped of (always a one, not transmitted) and the next four MSB bits set into “Man”. The Exp part will be the real exponent adjusted for the new bias (32) and set into Exp.

This is a simple C routine to unpack the F8 coded data:

```
int unpack_f 8(int acc)
{    int exp;

     exp=(acc >> 4) & 0x0F;
      if(exp > 1)
        { acc=(acc & 0x0F) | 0x10;
          acc=acc << (exp-1);
       }

     return acc;
}
```

7.2 Data compression.
The ICA-IMA compression consists of two functional parts: a preprocessor and an adaptive entropy coder.

The preprocessor first converts a 16 or 32 bit word to a hybrid floating 8-bit byte (F8-code). It then uses the delayed predictor technique (to calculate δ’s) for the mapping process.

The bit compression uses Rice’s adaptive coding (CCSDS 121.0-B-1). From above (F8-code) the implemented compression software works with 8 bit length data only (Types=0-7).

7.2.1 Compressed data layout.

The compressed data layout consists of records subdivided into blocks. With exception for type 0, sub 1 each record holds compressed data for 128 bytes. The layout is a variant of the CCSDS 121.0-B-1 recommendation.

The differences are:

1) A Record always starts with a record length in bytes and if required a bit padding field at the end to ensure whole bytes. This way the next record may me located (except for some special situations) if the decompression fails in a record.

2) The order of Fundamental sequences (Fs) and Split bits (Sb) are Fs+Sb,Fs+Sb….. instead of Fs,Fs…. ,Sb,Sb… Again if a decompression fails in a block, the already decompressed bytes may be correct. This also allows for short blocks, short records at the end of a fully compressed data area.

3) The number of zero run blocks is given as a fixed binary 3 bit field instead of a Fs code.

4) The type 0 second extension (sub=1) do not use the CCDS one. Instead a special zero run record is introduced for the ICA-IMA experiments. The reason is that both experiment have large areas in shadow. When in shadow all data are zeroed out giving rise to long sequences of records with zero run blocks. Instead of counting zero run blocks, zero run records are counted. Example record: 0x03,0x00,0x17 would decompress to 128*8=1024 bytes of 0x00.

For details see CCSDS-121.0-B-1.

Record.

Length	Reference	Block 0	Block 1	……..	Block N	Pad

Block (Type 0.0)**.**

Type = 0	Sub=0	Block count-1

Block (Type 0.1)**.**

Type = 0	Sub=1	Record count-1

Block (Type 1-6)**.**

Type=1-6	Fs0+Sb0	Fs1+Sb1	………	FsN+SbN

Block (Type 7)**.**

Type = 7	Byte 0	Byte 1	………	Byte N

Fields

Name	**Bits**	**Short description**
Length	8	The total length in bytes of the record
Reference	8	The uncompressed reference value for the record
Block	Variable	A block of bits holding compressed data for 16 bytes *)
Pad	Variable	Bit padding to ensure whole bytes for a record
Type	3	The compression type (0-7)
Sub	1	The type 0 subtype extension (0-1)
Block count-1	3	Number of zero run blocks –1
Record count-1	4	Number of zero run records – 1
FsN+SbN	Variable	The Fundamental sequence + the Split bits for byte N
Byte	8	Un uncompressed byte

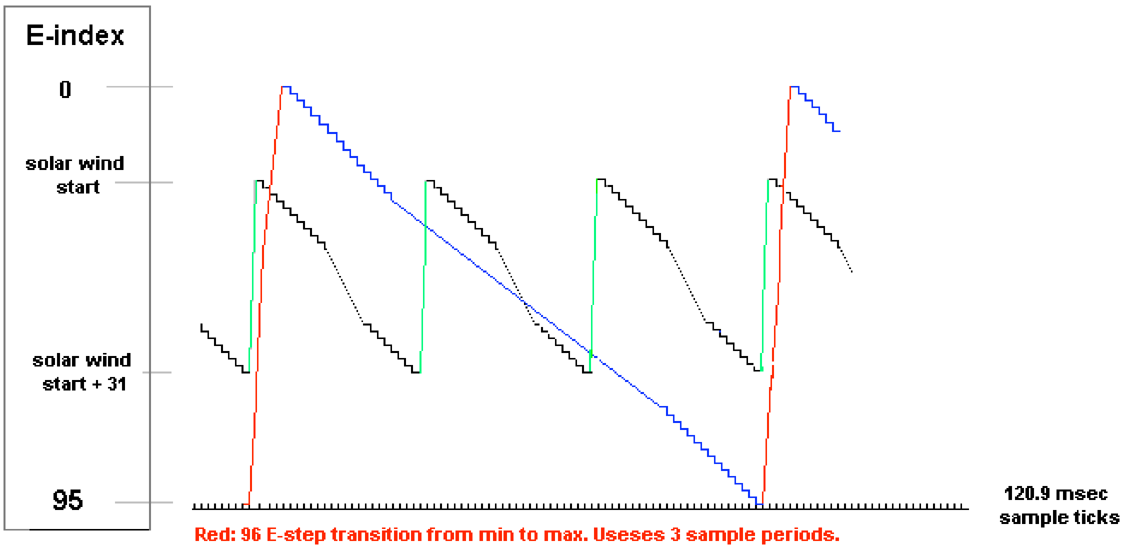
*) Block 0 only holds data for 15 bytes. The Reference gives the 16:th byte.

8.0 Timing and time tagging.

8.1 General.

Disregarding any clocks like DPU master, the experiment operation (measurement) is governed by the imager sampling time (120.9 msec). The imager supplies a mass * azimuth matrix for a given energy and elevation (polar angle) per sample. The energy and elevation is controlled by changing electro-static HV deflection systems. The energy cycle always starts at the maximum energy and is then stepped down to the minimum level. The cycle is then repeated by forcing the HV to its maximum. The change from low to high is allocated one sample period to ensure proper HV relaxing. The maximum number of energy levels are 96. There are, however, modes that use 32 consecutive levels only out of the 96. They also require a sample period for HV relaxation. Thus for a proper coherent operation, the 32 level mode requires 33 sampling periods leading to 99 sampling periods for the 96 level energy modes. The “dead” HV transition period is always placed in front of each energy scan (1 sample for 32 energy levels and 3 for 96 energy levels). The figure below shows the principles.

Symbolic sketch of the ICA/IMA energy stepping for 96 and 32 E-levels.
They are organized to always be in synchronism.



Red: 96 E-step transition from min to max. Useses 3 sample periods.
Blue: 96 E-steps. Stepping down.

Green: 32 E-step transition from min to max. Uses 1 sample period.
Black: 32 E-steps. Stepping down.

8.2 Time tagging.

The term time tagging here refers to the ICA/IMA science format (EDF=Experiment Data Format) time transmitted in the header of each EDF. This time always refer to the start of the first sample in the data collection scheme for the current format. That is, any HV relaxing period is NOT included, but may have to be taking into account for subsequent cycles (energy and/or elevations). The EDF time is composed of the time delivered by S/C and an internal timer. What ever, the accuracy of the S/C timer the ICA/IMA is scaled down to 31.5 msec accuracy. Also note that the ICA/IMA EDF time is 3 bytes wide only. More significant bits must be taken from tm packet times. All times are with respect to S/C time. Any correlation/correction to UTC should be done after the ICA/IMA 3 byte time has been complemented with more significant bits from the ESA packet time. Bee observant that when the 3 byte ICA/IMA timer swaps around, the packet MSB may already have been updated by one prior to be applicable for the ICA/IMA time. This is due to the ICA/IMA tm fifo saving of tm data. This will not happen very often and can always be corrected for. The reason for only 3 bytes of ICA/IMA time tagging is to reduce the overhead by the header in the low rate tm modes. The ICA/IMA timer will swap around about once per 6 days.

9.0 Data reduction considerations.

The experipents (ICA/IMA) utilizes an automatic way of adjusting the data reduction in order not to produce too much data for tm down load. This is accomplished by integrating “adjacent” samples together. There is no attempt onboard to divide down the counts by number of samples integrated Mostly not advisable for “Poission” counting statistics. The number of samples can, however, be obtained on ground by the knowledge of the onboard steering tables. This is not a subject of this manual.