PLASTIC IDPU Software Requirements Document

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Overview of PLASTIC Instrument operation

PLASTIC covers the full azimuthal range (ie. in the ecliptic plane) at all times, but needs to step through energies-per-charge and polar angles. The polar angle steps from +20 to – 20 degrees in 1.33 degree steps (30 steps, plus 2 steps close to zero volts). In normal mode, the ESA voltage is stepped in logarithmic increments in 128 steps. For a full cycle, the ESA will sit at one voltage, while the deflector voltages sweep through their full set of values. Then the ESA voltage will continue to the next step. Each deflection step takes 14.2 msec, so a full set of angles (32 steps, including transition steps) takes 455.4 ms, and a full cycle will take 1 minute (128 ESA steps plus some overhead).

Because all solar wind ions flow with approximately the same speed, the E/q selection of the entrance system acts to separate solar wind ions by mass/q. Because the heavy ions are normally not fully ionized, their mass/q is normally larger than 2. Thus the heavy ions are observed at the higher E/q steps than H+, and to some extent, He++. Because there is a large difference in fluxes of H+, He++ and heavy ions, there are two entrance systems for the solar wind ions. One entrance has a large geometric factor, for the low abundance heavy ions, and one entrance has a small geometric factor for the H+ and possibly He++ ions. At the high E/q steps, when we are mainly measuring the heavy ions, we use the main, large geometric factor, aperture. At lower E/q steps, we need to switch to the "S-channel" low geometric factor aperture to measure the protons. The energy at which to switch between the two entrance systems is determined by the DPU.

The PLASTIC instrument is functionally divided into two halves, one which has Solid State Detectors (SSD's) as well as MCP's, and one which just has MCP's. In order to accommodate the SSD's, the length of the flight path is different for the two sides. There are two sets of time-of-flight electronics, one for each half. There are four sets of position electronics, one for each quadrant.

DPU PLASTIC Processor Tasks

The DPU tasks can be divided into 3 sub-sections:
1) DPU Control tasks
2) DPU Data tasks
3) DPU table generation tasks.

1) DPU Control tasks

The DPU is responsible for the following tasks:

1.1)   Receiving, decoding and routing commands to the instrument
1.2)   Controlling sweep and deflector HV, including determining energy step to switch between entrance systems.
1.3)   Emergency response.
1.4)   Triggering the "Tracking Mode", and controlling the stepping sequence for the tracking mode.

1.1. Receiving, decoding and routing commands to the instrument

The DPU is responsible for receiving, decoding and routing commands initiated on the ground. We will also define a number of standard configurations for the instrument (e.g. Standby, Maneuver-safe, Calibration). The DPU will store the parameters for these states, and execute them on command.

1.2. Controlling deflector voltages

The DPU is responsible for choosing the stepping tables for the ESA and deflectors. There may be more than one table (stepping mode), selectable by command. There will be two sets of deflection tables, one for using the S-channel and one for using the main-channel. At the start of a cycle, the main channel is used. The DPU will monitor one rate from the monitor rates packets, which are sent every deflection step (every 14.2 ms). By default the rate will be the "start rate" (SF), from the Solar Wind side of the instrument, but another rate could be selected. When the rate exceeds a critical value (selectable by command) for any packet (deflection step) within an E/q step, the DPU will send the command to switch to the S-channel for the subsequent E/q steps. The DPU will be processing tasks in a polled loop. Because there may be some time lag before the DPU processes the monitor rates data, this switch may occur 2 (but not more than 2) E/q voltage steps after the critical count rate was measured. This corresponds to a DPU reaction time of about 1 s.

1.3. Emergency Response

The DPU will read critical housekeeping values and execute emergency procedures if the HK values fall out of range. Some examples are:

> 1.3a. If Current limits are exceeded, turn voltages down and instrument off.
> 1.3b. If HV discharges, step the HV back up to nominal value (like CLUSTER)
> 1.3c. The DPU may need to respond to spacecraft flags of critical events. For example it may

need to automatically safe the instrument during thruster operations, and then automatically reconfigure the instrument at the end.

1.4. Triggering the Tracking Mode

Note this is not well defined at this point, and is considered a low priority.

There will be a special mode triggered either by command or by a trigger from other IMPACT instruments, where we need to get high time-resolution proton data, at the expense of the heavy ion data. To do this, the DPU will need to find the peak in the SW proton/alpha distribution. The DPU will then indicate the step in the table where the sequence should start, and the number of steps it should take (e.g. 10 steps around the H+ peak). Our baseline is that we will still step through all 30 polar-angle deflection steps. In this scenario, the DPU still reads the data arrays every 455.4 ms, and we will get a proton distribution every 4.55 s.

2) DPU Data Tasks:

There are five types of data that the DPU will process:

2.1 HK data
2.2 Monitor rate data
2.3 Matrix Rate Data (from Classification Board)
2.4 Raw Event data (PHA data)
2.5 Beacon Mode data

In all cases the DPU must format the data for telemetry, including adding header information for identifying product type and data collection time. There will be a limited number (4?) of data modes. The selection of data which is put into the telemetry dependes on the mode. The modes defined in this document are 0) Science mode 1) Engineering mode. There may also be a "Table Dump Mode" which dumps the tables used for on-board classification. For this mode, the DPU would not have to process the data, but just pass the table information into the telemetry. Also, as mentioned above, there may be a "Tracking Mode", which would also require a different data products in the telemetry.

2.1   HK Data

A housekeeping packet containing a number of instrument voltages, currents and temperatures will be sent to the DPU, to be formatted for telemetry. A normal priority packet will be sent every 30 s and a high priority packet will be sent every 5 seconds. This is shown in Table 1. The DPU will monitor these values, and check them against established limits. If the values go outside the limits, a pre-defined procedure will take place. For example, if a current gets too high, the instrument may be shut off.

Table 1. Housekeeping data received by DPU

	Number of items	Bits/item	Total bits	Total bytes	Time interval (s)	Bit rate (bits/s)
Normal Priority HK	40	16	640	80	30	21.33
High Priority HK	8	16	128	16	5	25.6

A subset of the housekeeping data will be put into telemetry. In science mode (mode 0), the telemetry will contain the 48 housekeeping values once/minute. The values will either be a snapshot (one out of two of the low-priority, one out of 5 of the high priority), or an average over the time period. We will be able to command whether to be in snapshot or average mode. In engineering mode (mode 1), the full set of housekeeping, both normal and high priority, will go into the telemetry at full time resolution.

2.2 Monitor Rate data

The monitor rates data consists of the raw rates from individual 16-bit counters and from checks for logical coincidences in the instrument. There will be about 32 rates (exact number TBD). The packet will contain the rate data, the E/Q step, and the deflection step information.

These will be sent in a packet to the DPU every deflection step (every 14.2 ms). From this, two types of data products will be formed. In science mode (mode 0), for one rate (selectable, but default would be start rate, SF) we would keep full angle angle and time resolution for half the energy steps The first step to use would be commandable, and the product would then use the subsequent 63 steps. For the full set of rates we will create a data product which sums the rates in energy, angle and time to get a smaller set. This summed product would sent out once every 5 cycles. Each set of 4 adjacent energies, and 4 adjacent deflector angles would be summed, and the product would be accumulated for 5 cycles (5 minutes). In Engineering mode (mode 1), the "normal" rates would come out every minute, and additional rates would be put into the telemetry at high resolution.

Table 2. Monitor Rates data products formed by DPU in science mode.

	N Rates	N Energies	N Polar	total items	bits/item	total bits	Total bits Compressed	Time res	bits/s
Normal	32	32	8	8192	16	131072	65536	300	218.45
High-res	1	64	32	2048	16	32768	16384	60	273.07

2.3 Matrix Rate Data

The 16-bit accumulators from the classification board will be sent to the DPU after every deflection cycle (455.4 ms). The contents of the accumulators are listed in table 3.   This large array will be broken into smaller packets for transmission to the DPU. The accumulated data must then be further summed and processed as listed below.

Table 3. Accumulated products on Classification board.

Name	Bin_dat type	Class bins	Pos. bins	Def. bins	Energy steps	# of sections	SECTION *	Total bins	bits/ item	Total Bytes
SW-all	Sw-all	1	32	32	1	1	0 or 1	1024	16	2048
SW-H/alpha-Doubles	sw H alpha	2	32	32	1	1	0 or 1	2048	16	4096
SW_alpha_Triples	sw H alpha	1	32	32	1	1	0 or 1	1024	16	2048
SW Z>2	sw Z>2	15	16	8	1	1	0 or 1	1920	16	3840
Wide-angle, Triples	Supra wide	15	8	1	1	1	2	120	16	240
Wide-angle, Double	Supra no E	7	8	1	1	2	2,3	112	16	224
SW_PHA_Priority_rates	Pha pri rates	4	1	32	1	1	0 or 1	128	16	256
WAP_PHA_Priority_rates	Pha pri rates	2	1	1	1	2	2,3	4	16	8
PHA Data								512	48	3072
Total										15832
							*0-SW-main channel, 1-SW-S channel, 2-WAPwSSD 3-WAP_no_SSD			

2.3a   SW Proton and Alpha data

From the instrument, there are three arrays which contain the solar wind proton and alpha data. The first array (SW-all) contains the proton/alpha data together, with only angular binning. The second (SW-H/alpha-Doubles) contains data classified using the time-of flight: there is a 30-azimuthal bin x 30-polar bin array for each of the two species. The third (SW_alpha_Triples) contains the alpha data classified using the both time-of-flight and energy measurement. By command, we will be able to choose the array used for calculating proton moments. A reduced distribution function from all arrays will be telemetered to the ground.

So that the DPU does not have to store a whole array of data, the telemetered reduced distribution functions will be based on the peak from the previous cycle. The moments will be calculated over a fixed (commandable) energy range which does not depend on the previous measurements.

The following processing must be done. From the previous array, or (to start the sequence) using a programmed default, there must be values for the proton peak position bin (PP), the peak deflection bin (DP), and the peak energy step (EP). Similarly there must be values for the alpha's, PA, DA, and EA.

1) calculate13 moments for protons, using the commanded energy range array, the proton peak position bin (PP), the peak deflection bin (DP) and commanded Emin, Emax. The angle bins used

for the calculation would be PP-7 to PP+8, and DP-3 to DP+4. (ie 16 bins in azimuth and 8 bins in deflection step). The moments will be calculated to 16 bits.

3   2) Form reduced distribution functions, for protons and alphas. There will be four distribution functions total, from the 4 SW proton/alpha arrays. If the proton peaks are EP (peak energy step), PP(peak position bin) DP(peak deflection bin) and the alpha peaks are EA (peak energy step) PA(peak position bin) DA (peak deflection peak), then the min and max energies and angles to use are given in the following table 4. Note in the following, we are using the energy stepping sequence number, and the energies step from high energies to low energies. So the highest energy step would be EP=0, and the lowest energy step would be EP=128. Similarly EP+4 corresponds to a lower energy than EP, and EP-5 corresponds to a higher energy than EP.

Table 4. Bins to use to form the reduced proton and alpha distributions.

Source Array	Reduced Array	Class bin	E min	E max	Esteps	POS min	POS max	Pos bins	DEF min	DEF max	Def bins
SW-all	H_alpha	0	EP+4	EP-15	20	PP-3	PP+4	8	DP-3	DP+4	8
SW-H/alpha-Doubles	H+ Peak	0	EP+4	EP-5	10	PP-3	PP+4	8	DP-3	DP+4	8
SW-H/alpha-Doubles	He++ Peak	1	EA+4	EA-5	10	PA-3	PA+4	8	DA-3	DA+4	8
SW_alpha_Triples	He++ TCR	0	EA+4	EA-5	10	PA-3	PA+4	8	DA-3	DA+4	8

3)   determine the energy, deflection angle, and position angle of the peak from the selected proton array. This info is used to generate the reduced distribution function for the next cycle.

4) Determine the energy, deflection angle, and position angle of the peak from the alpha-array. Again, this can be done on a packet by packet basis. As each new packet comes in, check the values against the previous peak. If it is higher, replace the EA, PA, and DA values. This will be used to generate the next alpha distribution. It will be commandable, whether to use the SW-H/alpha-Doubles array for the peak determination or the SW_alpha_Triples.

The four distributions will be telemetered every cycle (1 min). The header in formation in the packet needs to include the Peak (or first) energy, position, and deflection used in for the array.

Commandable parameters:
      Minimum and maximum energy step to use for calculating proton moments
      Minimum and maximum energy step to use for calculating alpha moments
      Array for proton moments
      Array to use for alpha-peak determination
      Default peak values

2.3b   **Heavy Ion Data**

The other "matrix rate" products must be accumulated in time, and angle to create "data products" that can be telemetered at our available telemetry rate. Table 5 gives the source arrays, and the summing that needs to be done to generate the final array.

Table 5. Bins to be summed to form the heavy ion distributions.

Source Array	Reduced Array	Sec.	Total Class bins	Summed Energy bins	Total Energy bins	Summed Pos. Bins	Total Pos. bins	Summed Def. Bins	Total Def. Bins	Summed Cycles	total bins	Bits /item	total bits
SW Z>2	SW_Z>2 - H	0 and 1	2	1	128	2	8	1	8	5	16384	16	262144
SW Z>2	SW_Z>2 - L	0 and 1	13	1	128	2	8	8	1	5	13312	16	212992
Wide-angle, Triples	WAP-SSD_TCR	2	15	1	128	2	4	1	1	5	7680	16	122880
Wide-angle, Double	WAP-SSD_DCR	2	7	1	128	2	4	1	1	5	3584	16	57344
Wide-angle, Double	WAP-noSSD-DCR	3	7	1	128	1	8	1	1	5	7168	16	114688
SW_PHA_ Priority_ rates	SW_Priority_ rates	0 and 1	4	1	128	1	1	2	16	5	8192	16	131072
WAP_PHA_ Priority_ rates	WAP_Priority	2 and 3	2	1	128	1	1	1	1	5	256	16	4096
Total storage needed													905216

2.4 Raw Event data

We need to collect a sample of raw events, which are used for high resolution science analysis, as well as instrument diagnostics. We want to maximize the number of minor ions collected, and also collect a selection of ions from the different sections of the instrument. Thus we need to have a prioritizing scheme for selecting the ions. The ions need to be tagged with their priority classification. This comes from the classification board. Then, a selection of these events needs to be put into the telemetry.

On the classifier board, the data have already been sorted by priority. There are 6 priorities, 2 for the WAP section (WAP P0 and WAP P1) and 4 for the Solar Wind Section (SW P0, SW P1, SW P2, SW P3). The DPU is sent up to 512 PHA words for one energy step. These will be already divided as up to 32 WAP P0, 32 WAP P1, 64 SW P0, 64 SW P1 and 160 SW P2 and 160 SW P3. The DPU is responsible for down-selecting the data, but making sure we still emphasize the heavy ions in a full packet. The process would be something like this:

On average the DPU can send down 6 events per step. We will handle the PHA data in sets of 2 E/Q steps. The DPU can send down 12 events every 2 steps. This data is divided into 6 priorities: 2 WAP priorities and 4 SW priorities. We will specify, on average, how many of each priority we should collect every 2 steps, with the total adding up to 12. For example, we would specify:

1 WAP P0 (H+ and He++)
1 WAP P1 (Heavies)
1 SW P0 (H+)
1 SW P1 (He++)
4 SW P2 (heavies)

4 SW P3 (heavies)

The DPU will have 2 buffers, a "primary" buffer, of size 768*48 bits = 36864 bits, divided into 6 priorities, and a secondary buffer of approximately half the size of the primary. The "primary" buffer will be used to collect events from all priorities and all energies with approximately the desired ratios. The secondary buffer will be used to store extra "high priority" events. Then any slots not filled in the primary buffer at the end of a full energy cycle can be filled by events from the secondary buffer.

The implementation could be the following:
There is a pointer for each priority that indicates how many events can be written into the primary buffer. For example, for SW P2, at energy step 0, the DPU increments the pointer by 4 (as specified above, so 4 SW heavy events can be written. At energy step 2, the pointer is incremented by 4 more. At this point, a maximum of 8 events could be accumulated. If only 3 were accumulated in the first 2 steps, 5 could be accumulated in the next 2 steps. If there were MORE than 4 SW heavy ions in the first 2 steps, the extra events would get written to the secondary buffer. Only events from WAP P1, and SW P2 and P3 get written to the seconary buffer.
During the cycle, the different priority buffers are kept separate. For example if there are not enough heavy ions to fill the buffer, these slots cannot be taken by protons. They are kept available for heavies at a later energy step. At the end of the energy cycle, if there are any open slots in any of the priorities which have not been filled, these will be filled by events from the secondary buffer.

The required memory in the DPU for this product is 768*48bits = 36864 bits, plus the size of the secondary buffer, and the completed packet would be sent out once per cycle (every minute).

2.5 Beacon Mode Data
The Beacon Mode data will be a subset of the normal data stream, with some small additional processing. Table 6 lists the data products for beacon mode, and the source of the data. There will also be a data quality flag associated with each parameter.

Table 6. Beacon Mode Data

Parameter	Resolution (min)	Items	Bits	Total bytes/min	Source	Additional Processing
SW H density	1	1	16	2	Moments	None
SW bulk H velocity (vx,vy,vz)	1	3	16	6	Moments	None
SW H+ temperature tensor	1	6	16	12	Moments	None
SW H+ heat flux tensor	1	6	16	12	Moments	None
SW He++ peak distribution	1	125	8	125	He++ Peak	Choose center 5-energy x 5-position x 5-defl matrix from alpha distribution

SW He++ peak energy step	1	1	8	1	He++ Peak	Info from header
SW He++ peak deflection step	1	1	8	1	He++ Peak	Info from header
SW He++ peak postion	1	1	8	1	He++ Peak	Info from header
Representative SW Charge states	5	5	8	1	SW Z>2	Summing selected bins from SW Z>2 matrix rates
Suprathermal rates	5	30	8	6	WAP_SSD_TCR WAP_SSD_DCR	Summing selected bins from Suprathermal matrix rates
PAC Value	1	1	16	2	HK	None
MCP Value	1	1	16	2	HK	None
Total byes/minute				171		

Summary of Data Requirements

Tables 7 and 8 give the total data rate to the DPU from PLASTIC, and the total storage requirements for the DPU to accumulate our data products.

Table 7. Total data rate from PLASTIC to the DPU

	Bytes	Time interval (ms)	Data rate (kbps)	Time to read at 1 Mhz (ms)
Classifier Board	15840	455.4	278.26	126.72
Monitor Rates	64	14.2	36.06	0.512
Normal Priority HK	80	30000	0.0213	0.64
High Priority HK	16	5000	0.0256	0.128
Total			314.36	

Table 8. Total data product storage required for DPU

	Size (bits)	Size(bytes)
Matrix Rates	956416	119552
PHA	36864	4608
Moments	208	26
Monitor Rates	163840	20480
HK	768	96
Total	1158096	144762

Science Mode Telemetry

Tables 9-13 give telemetry tables for the Matrix Rates, moments, PHA, and Monitor Rates and Housekeeping that show the size and time resolution of each data product in Science Mode.

Table 9. Matrix Rate telemetry (Science Mode)

	M vs M/Q bins	Energy steps	Pos steps	Def. steps	Number of items	Bits/item	Total Bits	Bits/item	Total bits	Time res (sec)	bits/s
H_alpha	1	20	8	8	1280	16	20480	8	10240	60	170.67
H+ Peak	1	10	8	8	640	16	10240	8	5120	60	85.33
He++ Peak	1	10	8	8	640	16	10240	8	5120	60	85.33
He++ TCR	1	10	8	8	640	16	10240	8	5120	60	85.33
SW_Z>2 - H	2	128	8	8	16384	16	262144	8	131072	300	436.91
SW_Z>2 - L	13	128	8	1	13312	16	212992	8	106496	300	354.99
WAP-SSD_TCR	15	128	4	1	7680	16	122880	8	61440	300	204.80
WAP-SSD_DCR	7	128	4	1	3584	16	57344	8	28672	300	95.57
WAP-noSSD-DCR	7	128	8	1	7168	16	114688	8	57344	600	95.57
SW_Priority_rates	4	128	1	16	8192	16	131072	8	65536	300	218.45
WAP_Priority	2	128	1	1	256	16	4096	8	2048	300	6.83
Total							956416				1839.79

Table 10. Moments telemetry (Science Mode)

Moments	Number	bits/moment	Total bits	Time res(secs)	minutes	bits/s
H-moments	13	16	208	60	1	3.47
Total			208			3.47

Table 11. Monitor rates telemetry (Science Mode)

	Rates	Esteps	Deflection Steps	Number of items	Bits/item	total bits	Compressebits/item	Comp. Total bits	Time res (sec)	bits/s
Normal Rates	32	32	8	8192	16	131072	8	65536	300	218.45
High-res rate	1	64	32	2048	16	32768	8	16384	60	273.07
total						163840				491.52

Table 12. PHA telemetry (Science Mode)

	N_events	bits/event	total bits	Time res(secs)	bits/s
PHA	768	48	36864	60	614.4

Table 13. Housekeeing telemetry (Science Mode)

	Number of items	bits/item	total bits	Time res(secs)	bits/s
Housekeeping	48	16	768	60	12.80

Table 14. Total Science Mode telemetry

	size (bits)	Time res	bits/s
SW proton/alpha Rates	25600	60	426.67
Most Other Matrix Rates	395264	300	1317.55
WAP-noSSD-DCR	57344	600	95.57
Moments	208	60	3.47
Mon_Rates_normal	65536	300	218.45
Mon_Rates_high	16384	60	273.07
PHA	36864	60	614.40
Housekeeping	768	60	12.80
Total			2961.97

Total does not include packet headers, and other overhead.

Engineering Mode Telemetry

Tables 15-17 summarize the telemetry for engineering mode.

Table 15. Housekeeping telemetry (Engineering Mode)

	Number of items	bits/item	total bits	Time res(secs)	bits/s
Normal Priority HK	40	16	640	30	21.33
High Priority HK	8	16	128	5	25.60
Total					46.93

Table 16. Monitor rates telemetry (Engineering Mode)

	Rates	Esteps	Deflection Steps	Number of items	Bits/item	total bits	Compressebits/item	Comp. Total bits	Time res (sec)	bits/s
Normal Rates	32	32	8	8192	16	131072	8	65536	60	1092.27
High-res rate	6	64	32	12288	16	196608	8	98304	60	1638.40
total						327680				2730.67

Table 17. Total Engineering Mode telemetry

	size (bits)	Time res	bits/s
Mon_Rates_normal	65536	60	1092.27
Mon_Rates_high	98304	60	1638.40
Normal Priority HK	640	30	21.33
High Priority HK	128	5	25.60
Total			2777.60

Total does not include packet headers, and other overhead.

3) DPU Table Generation tasks

The PLASTIC Classifier board requires 3 look-up tables to classify the data by mass and mass-per-charge. If the algorithms to generate these tables could be implemented in the DPU, this would save us time in command uploading. When the instrument is fully operational, the tables are expected to be static. New tables would need to be uploaded when the post-acceleration voltage changes or when some power loss results in loss of the current tables. There may also be refinement of some of the parameters after examing flight data that would require adjustment of the tables. The following show the algorithms for calculating 2 of the on-board tables. If these could be calculated onboard, it would save us significant upload commanding time. A new table would be generated by command, not automatically when a parameter (e.g. the PAC) changes. In general, all constants given below should be programmable.

3a) Calculation of NQ Table

The first table gives the mass-per-charge, for an input TOF-channel (10 bit) and the input E/Q step (7 bit). The algorithms are the following:

1) Convert time channels (Tch) to nanoseconds (Tmeas)

$$Tns = Tch * A + B$$
$$A = 0.25 \text{ (programmable)}$$
$$B = 0 \text{ (programmable)}$$

2) Convert E/Q steps to keV

$$E/q = D_1 * D_2^{[S]}$$

$S = 0$ to 127 is the ESA voltage step number

$$D1 = 0.2 \text{ (programmable)}$$
$$D2 = 1.05015096$$

3) Calculate Mass per charge for each T – E/Q pair

$$M/q = C_1 * [\text{ PAC} + (E/q) - C_2] * T_{meas}^2$$

$$C1 = (4.38E7)^2 / (1e9)^2/d^2$$
$$d = 5.8 \text{ (flight path in cm)}$$
$$PAC = 25 \text{ (post-acceleration value, in kV. When PAC changes, the tables change)}$$
$$C2 = 1.5 \text{ (estimate of energy loss, in keV)}$$

If using this value for C2 results in a calculated M/q value that is greater or equal to 11.0 amu/e, the event is re-classified using

$$C_2 = \text{xxx} \qquad (M/q \geq 11.0 \text{ amu/e})$$

4) Convert the mass-per-charge to a bin number.

The mass-per-charge is mapped into 254 logarithmically spaced bins

Desired Mass/Charge Range = MQ_{min} to MQ_{max}

N_Q Range = 1 to NQMAX

M/Q (lower bound of N_Q) = $MQ_{min} * k_Q^{(N_Q - 1)}$

$k_Q = (MQ_{max} / MQ_{min})^{1/NQMAX}$

The values for these parameters (or their equivalent) can be uploaded by ground command. The following default values reside in the CU:

MQ_{min} = 0.5 amu/e

MQ_{max} = 60.0 amu/e

NQMAX = 254

which defines k_Q = 1.01903

Each of the mass-per-charge values found in 3 needs to be assigned the appropriate bin number. This final table (an NQ value for every Tch (10-bit) –Estep(7-bit) pair) needs to be loaded into the classifier.

3b) Calculation of NM Table

This tables gives an output mass bin for an input time-of-flight channel (Tch) and an input Compressed energy channel. The algorithms are as follows:

1) Convert time channels (Tch) to nanoseconds (Tmeas)
   Tns = Tch * A + B
   A = 0.25 (programmable)
   B = 0 (programmable)

2) Un-compress the energy channel

Ech (compressed	Ecn (uncompressed)
0-95	Eun = Ecomp
96-143	Eun = (Ecomp-48)*2
144-191	Eun = (Ecomp-48*2) *4
192-239	Eun = (Ecomp-48*3) * 8
240-255	Eun = (Ecomp – 48*4) * 16

3) Convert uncompressed the energy channel to keV, and take natural log
   Emeas = Eun * A + B   A=2, B=0 (programmable)
   LnEmeas = ln (Emeas)

4) Calculate mass for each E-T pair from X = ln(Emeas), Y=ln(Tmeas)

$$\ln(M) = A_1 + A_2 * X + A_3 * Y + A_4 * X * Y + A_5 * X^2 + A_6 * Y^3$$

The coefficients (or their equivalent) can be uploaded by command. The following default values (or their equivalent) show example values:

For PAC = -25 kV, CF = 3.5 µg/cm2

$A_1 =$ 5.29633

$A_2 =$ -1.50530

$A_3 =$ -2.86483

$A_4 =$ 0.473693

$A_5 =$ 0.900633E-01

$A_6 =$ 0.783456E-01

5) For each mass for each E-T pair, assign the appropriate NM bin.

The particle mass M is mapped onto the mass-class axis which is subdivided into upto 96 logarithmically spaced N_M bins. The boundaries of the N_M bins are defined by the following relations:

Desired Mass Range = M_{min} to M_{max}

N_M Range = 1 to NMAX

M (lower bound of N_M) = $M_{min} * k_M^{(N_M -1)}$

$k_M = (M_{max} / M_{min})^{1/NMAX}$

The values for these parameters (or their equivalent) can be uploaded by ground command. The following default values reside in the DPU:

M_{min} = 0.5 amu

M_{max} = 95.0 amu

NMAX = 90

which defines k_M = 1.060033

The parameter k_M gives the mass resolution of the mass class bins (~6% for the default values shown above).