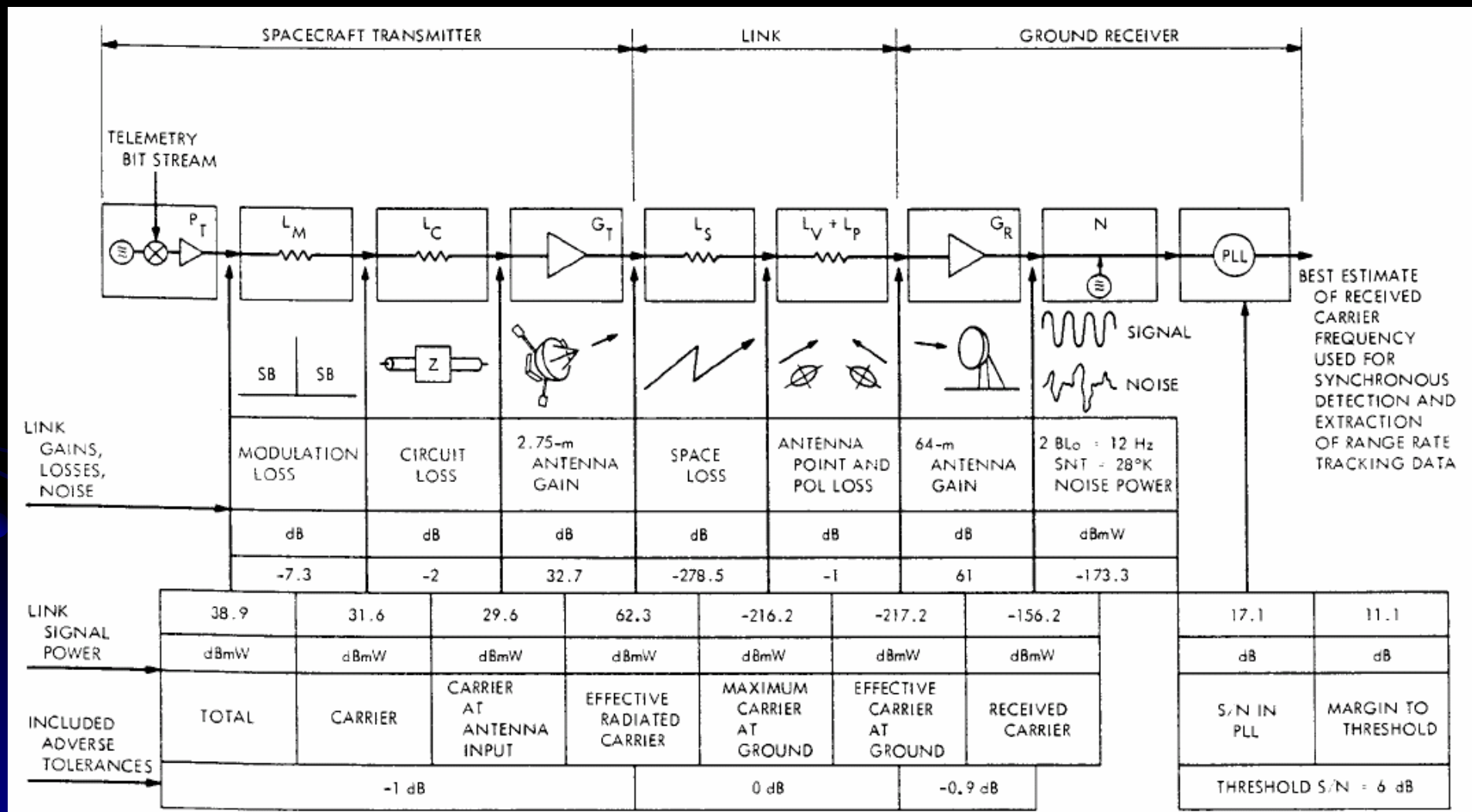


Master Data Records

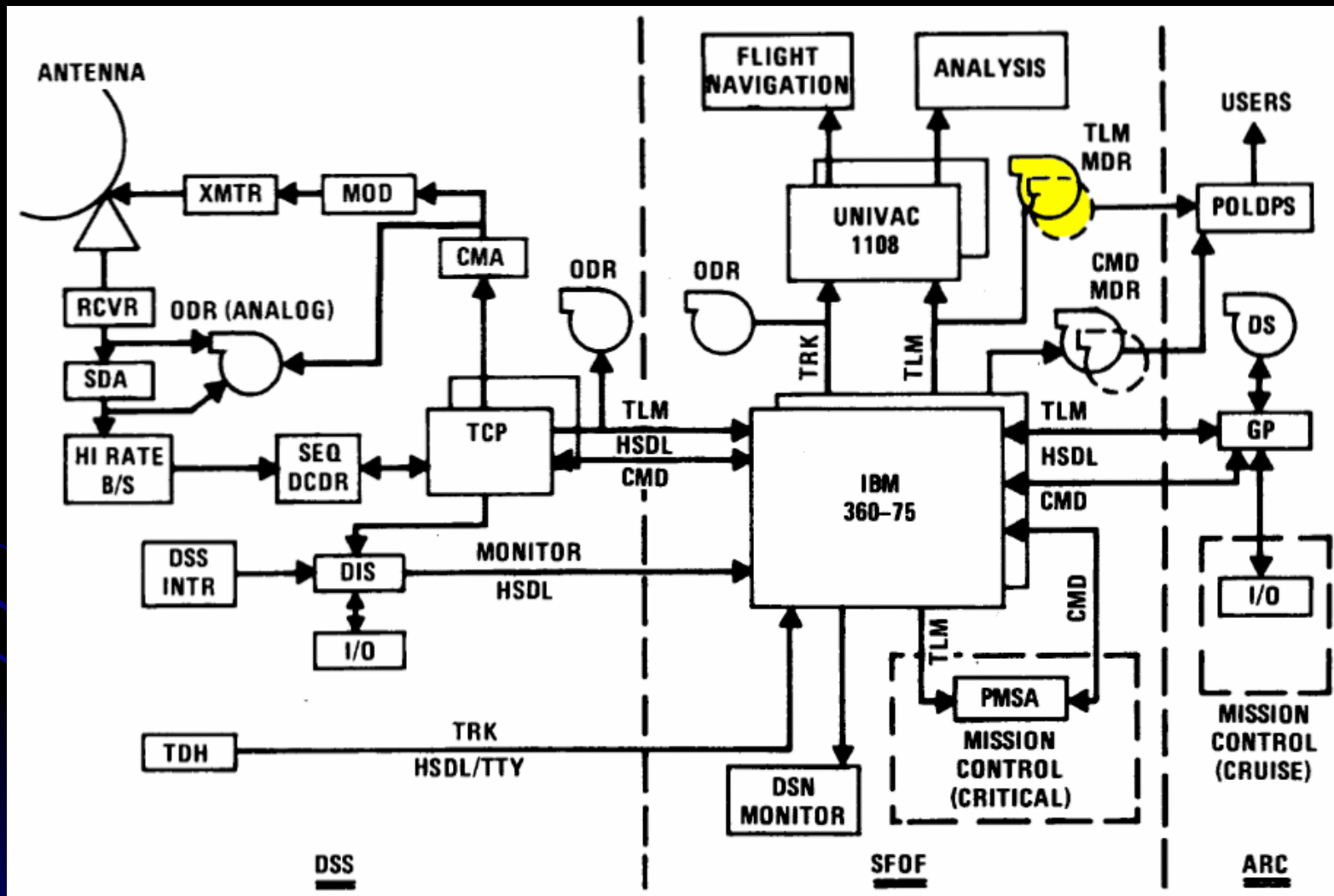
Preserving the Pioneer Legacy



Downlink Power Budget



Pioneer Ground Data System



Engineering Telemetry

- Data received by DSN packaged in MDRs
- MDRs contain
 - Reception characteristics
 - Science data
 - ***Engineering telemetry***
- Once science data was extracted and spacecraft operations no longer needed the data, MDRs were thought to be expendable

MDR media

- Originally, MDRs were stored on tape
- Tapes were transcribed to 128 MB 'floptical' discs
- Larry Kellogg copied all available 'flopticals' to modern media
- Total amount of data: 40 gigabytes



Decoding the MDRs

- Old documentation still available (PC-202, PC-261, ARC-221, DSN reports, etc.)
- Larry Kellogg's LabView code contains calibration values
- New code, first version: MDRs transcribed as human readable records
- New code, second version: Extracting specific parameters for selected time periods

Decoding Library

- Simple to use C/C++ callback library

```
bool GetMDRCallBack(const char *pszName, int nPos, time_t tStamp, int nmSec,
                    int nDQI, const char *pszField, const char *pszUnit,
                    const char *pszDesc, bool bSubComm, int nDValue,
                    const char *pszAValue)
{
    if (tStamp > g_tEnd) return false;
    printf("%s\t%d\t%d.%03.3d\t%d\t%c\t%d\t%s\n", pszName, nPos, tStamp, nmSec,
          nDQI, bSubComm ? 'Y' : 'N', nDValue, pszAValue);
    return true;
}
// ... //

GetMDR(atoi(argv[1]), atoi(argv[3]), argv[2], nSkip, GetMDRCallBack);

// ... //
```

MDR Structure

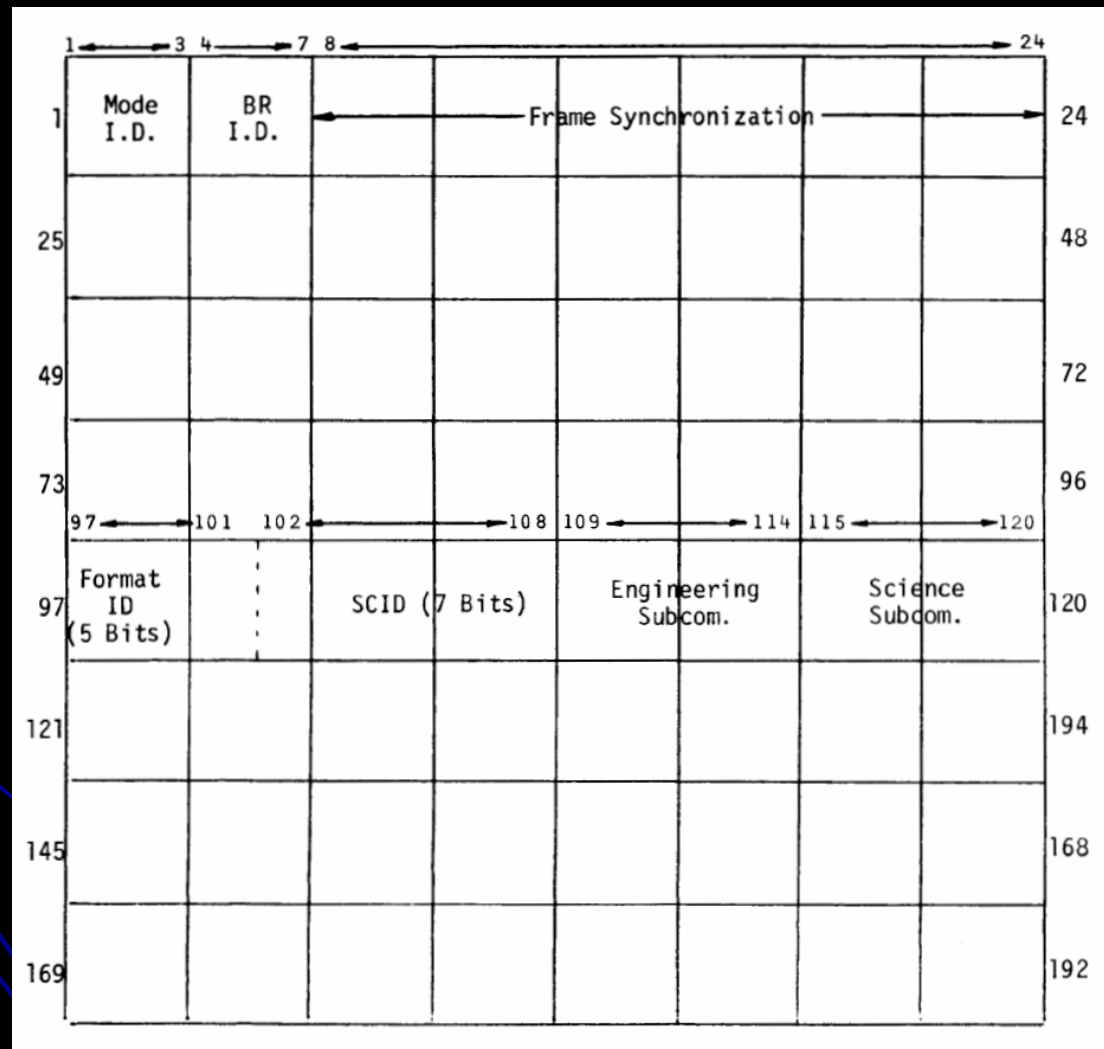
- MDR Record Structure

DSN Header (320 bits)
4 Data frames (192 bits/frame) or 2 Data frames (384 bits/frame)
DSN Footer (256 bits)

- Data frame formats

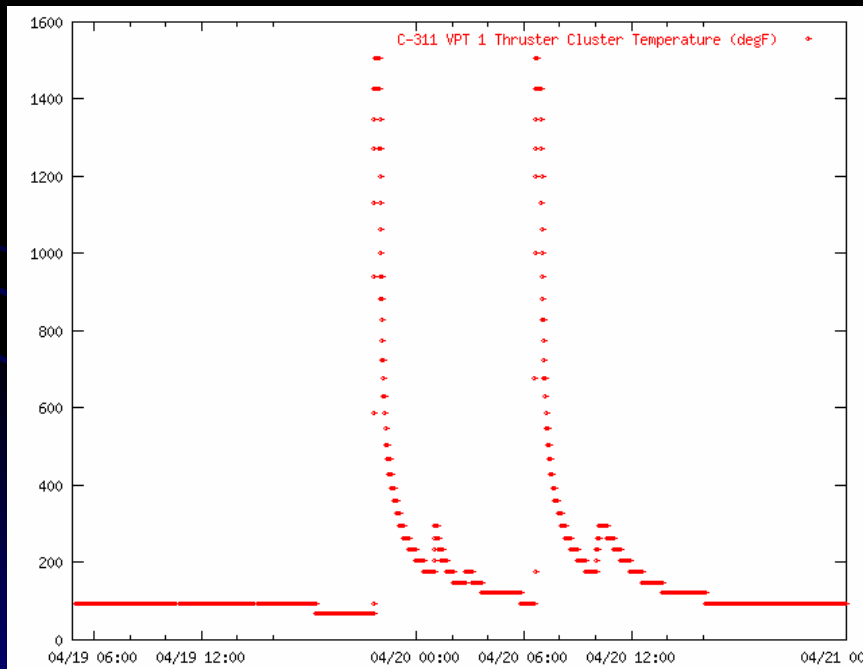
- Scientific (A, B, D): Telemetry in subcomm
- Accelerated (C1-C4): Telemetry only

Telemetry Frame

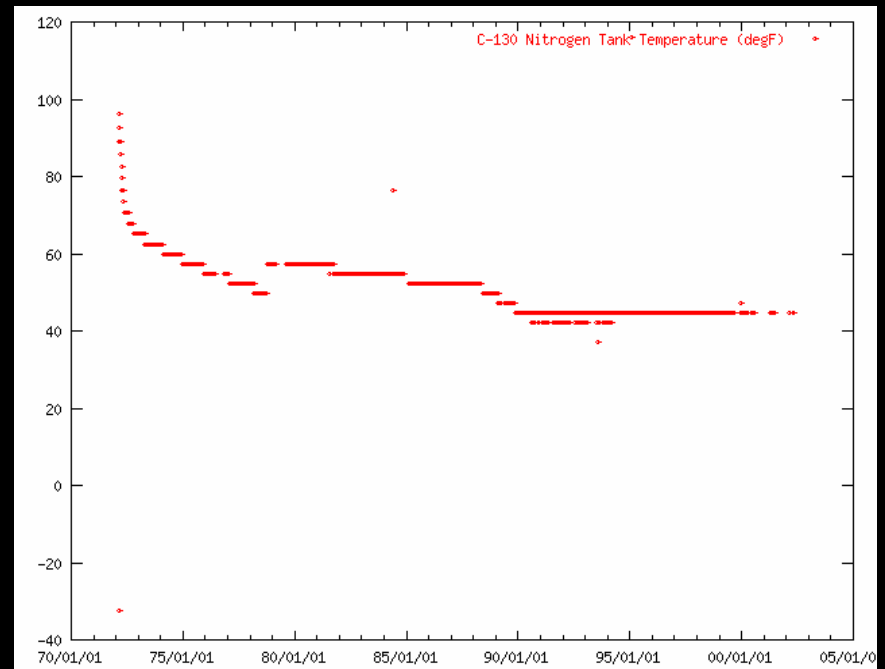


What do we see?

- Individual events (e.g., thruster firings)
- Long term trends (e.g., propellant temp.)



VPT1 temperature on board Pioneer 11 on April 19-20, 1974
(major course correction maneuver)



Nitrogen tank temperature on board Pioneer 10, entire mission.

How good is the data?

- We see 'bad' records
 - Reception errors?
 - Transcription errors?
- How can we detect errors?
- How can we quantify the error rate?
- Does it really matter? (Error shows up as random noise and doesn't affect trends)

Completeness

- Few significant periods of missing data
- Most notable: Pioneer-10 Jupiter encounter
- Other notables (outages of more than 3 days):
 - Pioneer-10 (continuous coverage until 1997, sporadic afterwards):
 - 1972 DOY 133-149
 - 1973 DOY 004-008, 060-067, 332-341
 - 1974 DOY 034-054
 - 1979 DOY 025-032, 125-128, 137-157, 171-200
 - 1980 DOY 173-182, 187-199, 248-257
 - 1983 DOY 329-348
 - 1984 DOY 346-359
 - Pioneer-11 (continuous until 1995):
 - 1973 DOY 056-064, 067-080, 082-086, 088-094
 - 1980 DOY 309-330, 337-365
 - 1982 DOY 318-365
 - 1983 DOY 001-050
 - 1984 DOY 343-357
 - 1990 DOY 081-096

Extracting the data

- Telemetry appears in most records in subcommutators
- Occasionally, accelerated telemetry was commanded (C-1 through C-4 formats)
- Data organized in unusual format (3-bit and 6-bit data words in 192-bit frame)
- Are we getting it right?
- How do we verify the extraction process?

Decoding parameters

- Parameter types: binary, bit field, analog
- A/D conversion: calibration
$$x = a_0 + a_1b + a_2b^2 + a_3b^3 + a_4b^4 + a_5b^5$$
- Different calibration values for the two spacecraft
- We have original calibration documents for Pioneer-10 (BFEC/ARC-037)
- Most values match; some don't, differences are minor but may need to be reconciled

What can we learn?

- Types of readings
 - Thermal
 - Electrical (voltages, currents)
 - Propellant pressure
 - Switches and sensors
 - Command and logic states
- Analog data is low-resolution (6 bits, 64 levels)
- Information about how sensors age?

Tools developed

- Data extraction (tab-delimited output)
- Thermal form (graphical parameter selection)
- Parameter plotting
- Trajectory plotting
- Preview plots
- Testing tools

Data Extraction Form

The screenshot shows a Microsoft Internet Explorer browser window titled "Pioneer-10/11 MDR retrieval form - Microsoft Internet Explorer". The address bar contains the URL "http://www.vttoth.com/PIONEER/getmdr.htm". The form includes the following fields and options:

- Spacecraft:** A dropdown menu with "Pioneer-10" selected.
- Subsystem:** A dropdown menu with "All Subsystems" selected.
- Parameter:** A dropdown menu.
- From:** A date range selector with dropdowns for year (1972), month (January), day (1), hour (00), minute (00), and second (00), followed by "to" and another date range selector with dropdowns for year (1972), month (December), day (31), hour (23), minute (59), and second (59).
- Skip every:** A text input field containing "1" followed by "records".
- Show only changed values**
- Display results graphically**
- Buttons:** "Submit", "Trajectories", and "Reset".
- Text:** "Or, go to the [thermal readings form](#)."

The browser's status bar at the bottom shows "Done" and "Internet".

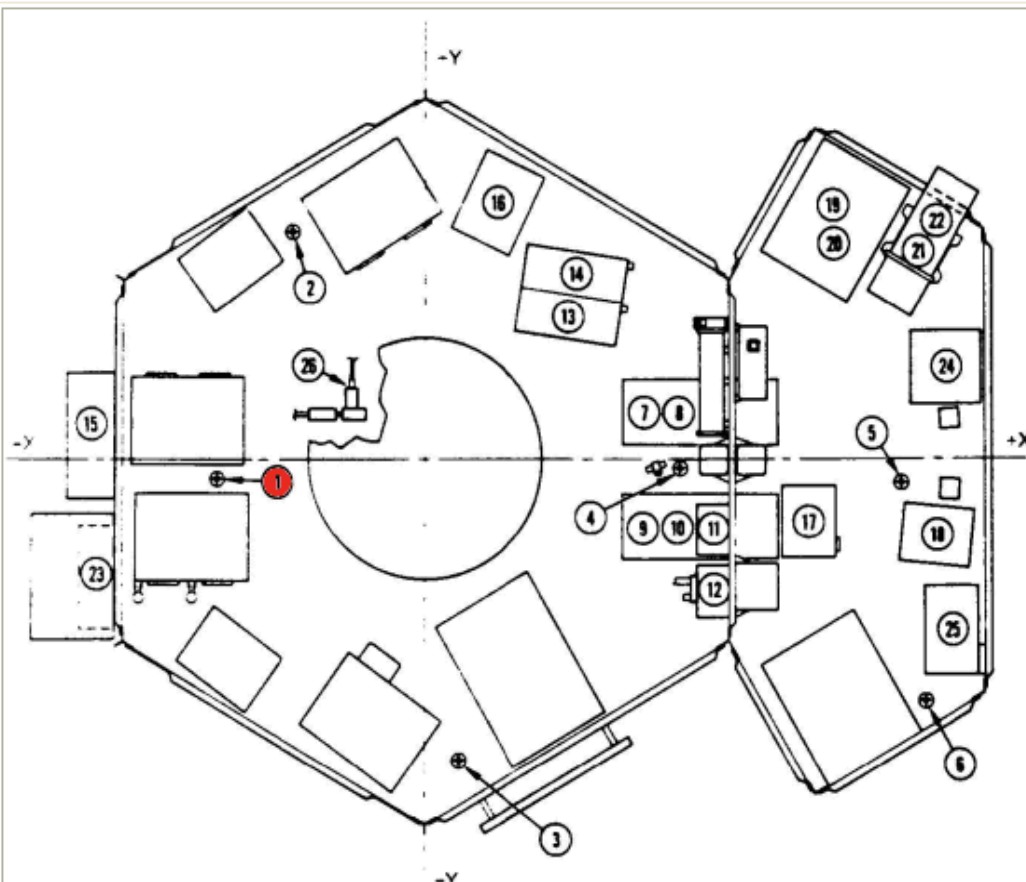
Thermal Form

Pioneer-10/11 MDR thermal readings - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites

Address <http://www.vttoth.com/PIONEER/thermal.htm> Go Links



Location: On platform

Spacecraft: Pioneer-10

Subsystem: All Subsystems

Parameter: C-301 S/C Platform Temperature 1

From: 1972 January 1 00:00:00

To: 1972 December 31 23:59:59

Skip every 1 records

Show only changed values

Display results graphically

Submit Reset

Return to [master selection form](#).

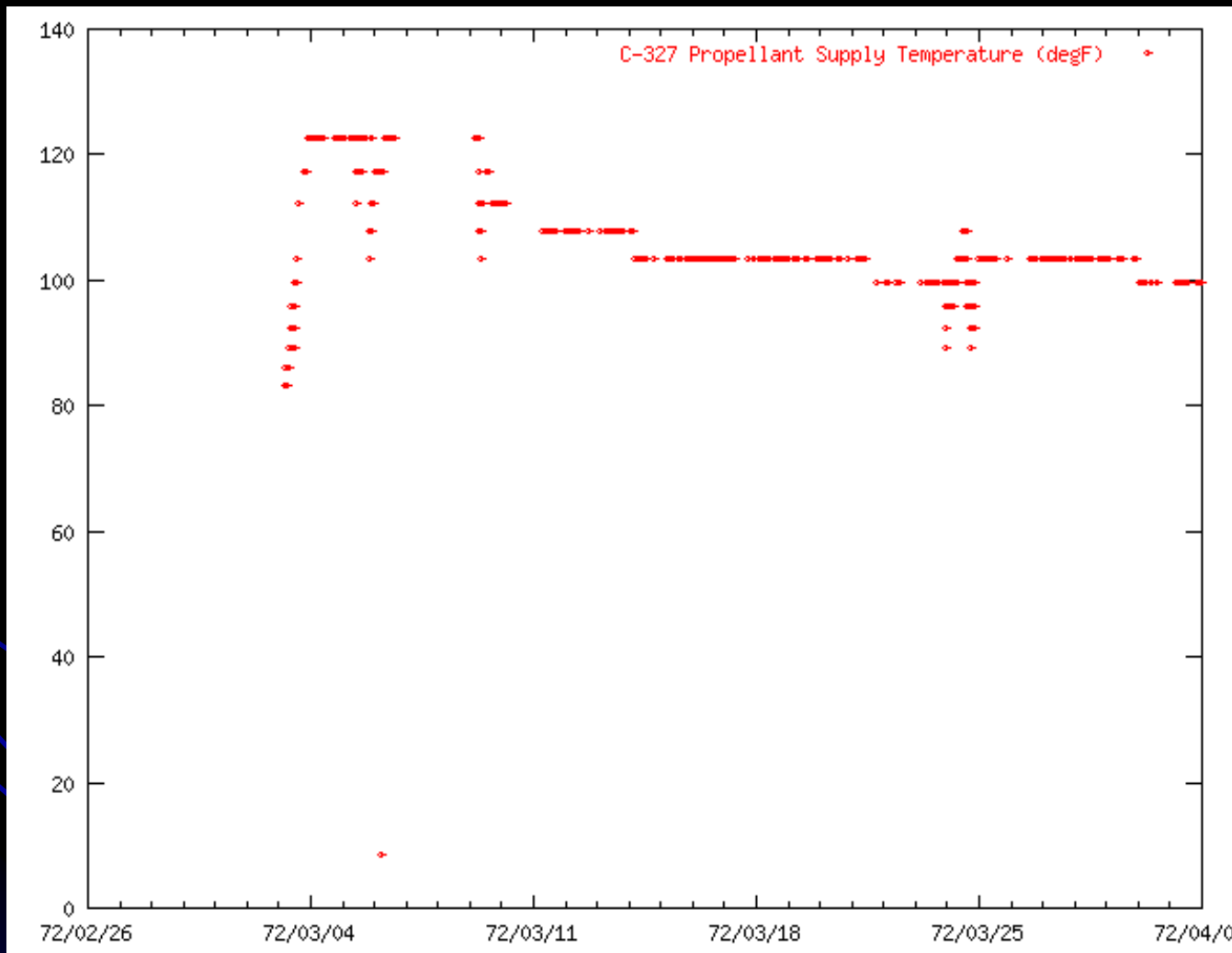
Done Internet

Tab-delimited output

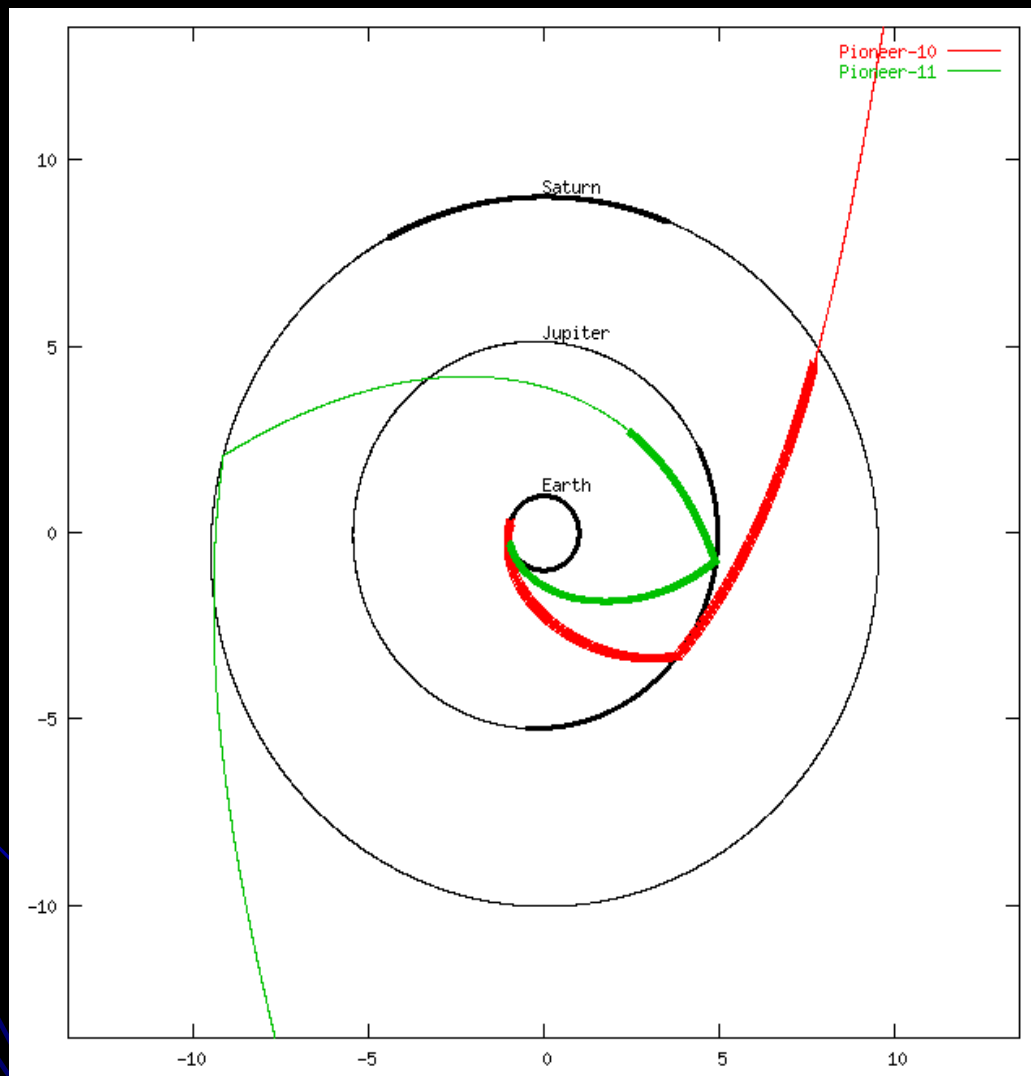
C-220 RTG 1 Hot Junction Temperature (°F)

Pathname/Filename	Pos	Timestamp	DQI	SubCom	Binary	Decoded
23P7204/m2372105.mdr	0	72075600.478	3	Y	37	956.346
23P7206/m2372125.mdr	100000	73843275.360	3	Y	37	956.346
23P7224/m2372202.mdr	0	80456400.543	3	Y	38	949.332
23P7228/m2372223.mdr	0	82270800.618	3	Y	38	949.332
23P7232/m2372268.mdr	0	86158801.684	3	Y	39	942.320
23P7233/m2372277.mdr	0	86936404.095	3	Y	39	942.320
23P7234/m2372303.mdr	0	89182800.218	3	Y	39	942.320
23P7236/m2372347.mdr	0	92984400.572	3	Y	39	942.320
23P7301/m2373001.mdr	0	94713001.248	3	Y	39	942.320
23P7301/m2373041.mdr	0	98168407.440	3	Y	39	942.320
23P7302/m2373080.mdr	0	101538000.656	3	Y	39	942.320
23P7305/m2373130.mdr	0	105858003.415	3	Y	39	942.320
23P7306/m2373141.mdr	0	106808400.273	3	Y	40	935.311
23P7308/m2373162.mdr	0	108622841.807	2	Y	40	935.311
23P7311/m2373197.mdr	0	111646803.283	3	Y	39	942.320
23P7314/m2373235.mdr	0	114930012.810	3	Y	39	942.320
23P7321/m2373305.mdr	0	120978000.027	3	Y	40	935.311
23P7322/m2373314.mdr	100000	121835568.020	3	Y	40	935.311
23P7325/m2373331.mdr	0	123224406.326	3	Y	40	935.311
.end						

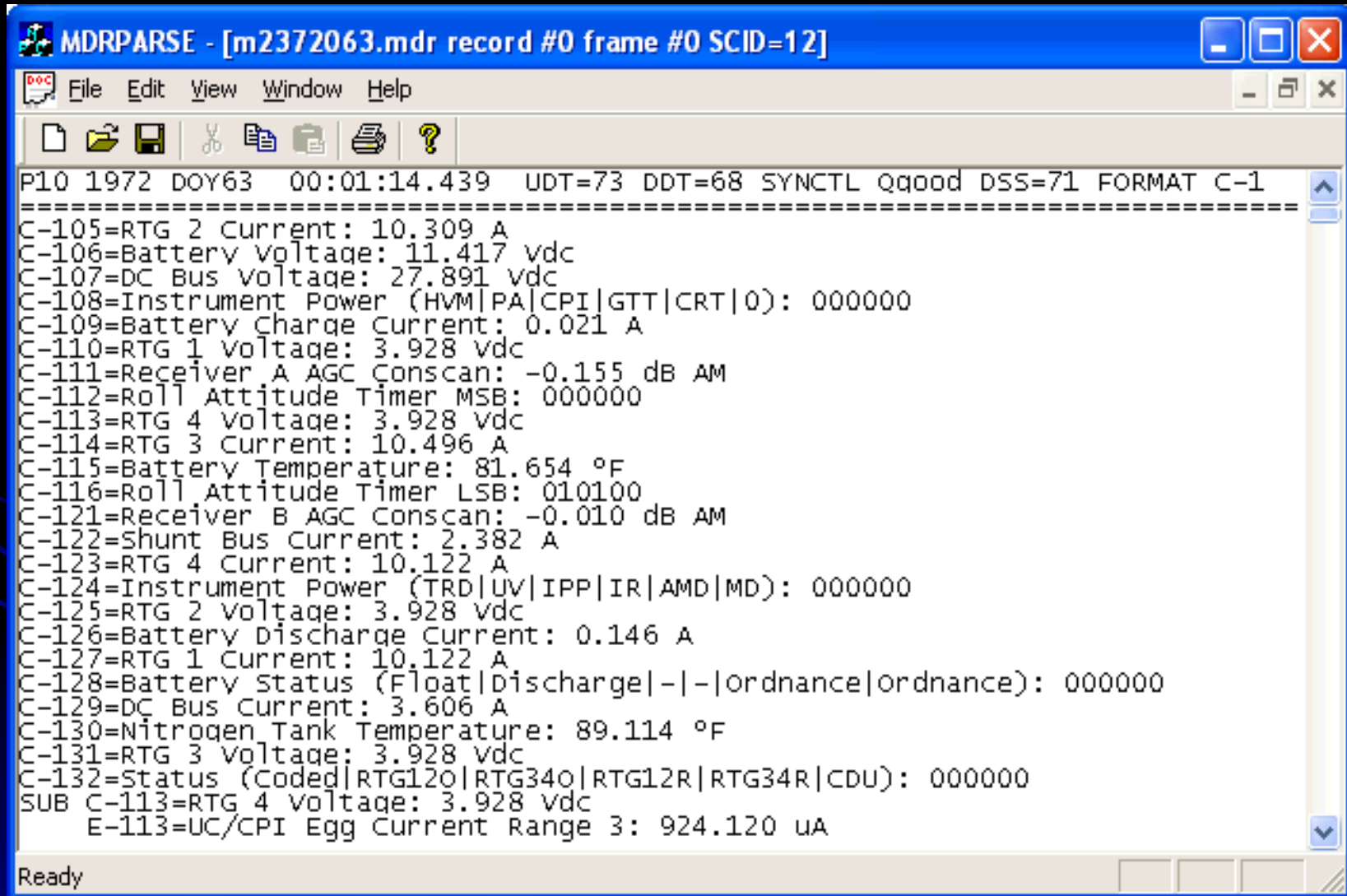
Parameter plots



Trajectory plots



Interactive parser



The screenshot shows a window titled "MDRPARSE - [m2372063.mdr record #0 frame #0 SCID=12]". The window contains a menu bar (File, Edit, View, Window, Help) and a toolbar with icons for file operations. The main text area displays a list of sensor data for a specific record. The data is organized into a header line, followed by a separator line, and then a list of sensor readings. The status bar at the bottom indicates "Ready".

```
P10 1972 DOY63 00:01:14.439 UDT=73 DDT=68 SYNCTL Qgood DSS=71 FORMAT C-1
=====
C-105=RTG 2 Current: 10.309 A
C-106=Battery Voltage: 11.417 vdc
C-107=DC Bus Voltage: 27.891 vdc
C-108=Instrument Power (HVM|PA|CPI|GTT|CRT|0): 000000
C-109=Battery Charge Current: 0.021 A
C-110=RTG 1 Voltage: 3.928 vdc
C-111=Receiver A AGC Conscan: -0.155 dB AM
C-112=Roll Attitude Timer MSB: 000000
C-113=RTG 4 Voltage: 3.928 vdc
C-114=RTG 3 Current: 10.496 A
C-115=Battery Temperature: 81.654 °F
C-116=Roll Attitude Timer LSB: 010100
C-121=Receiver B AGC Conscan: -0.010 dB AM
C-122=Shunt Bus Current: 2.382 A
C-123=RTG 4 Current: 10.122 A
C-124=Instrument Power (TRD|UV|IPP|IR|AMD|MD): 000000
C-125=RTG 2 Voltage: 3.928 vdc
C-126=Battery Discharge Current: 0.146 A
C-127=RTG 1 Current: 10.122 A
C-128=Battery Status (Float|Discharge|-|-|ordnance|ordnance): 000000
C-129=DC Bus Current: 3.606 A
C-130=Nitrogen Tank Temperature: 89.114 °F
C-131=RTG 3 Voltage: 3.928 vdc
C-132=status (Coded|RTG120|RTG340|RTG12R|RTG34R|CDU): 000000
SUB C-113=RTG 4 Voltage: 3.928 vdc
    E-113=UC/CPI Egg Current Range 3: 924.120 uA
```

Ready

Preview Plots

Plot thumbnails for Pioneer-10 - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites

Address <http://www.vttoth.com/PIONEER/PREVIEW/preview23.htm> Go Links

Plot thumbnails for **Pioneer-10**

This page contains pre-generated plots for all analog telemetry values. In order to optimize processing time (the entire data set contains over a billion records!) a variable sample size was used, to obtain a reasonable number of data points each year. Even so, it still took 25-30 minutes to extract the data for each plot. To view the full size plot, click on the thumbnail image. To view the data that was used to generate that plot, click on the label beneath the thumbnail.

To generate the plots, the following sampling values were used:

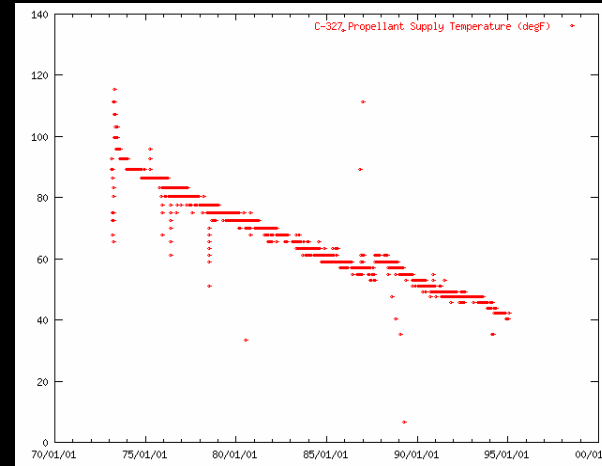
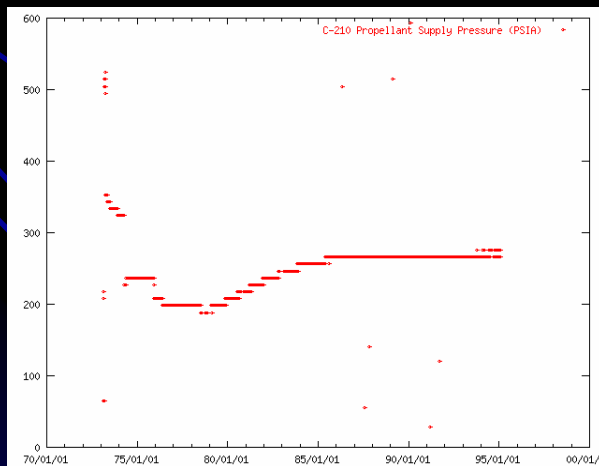
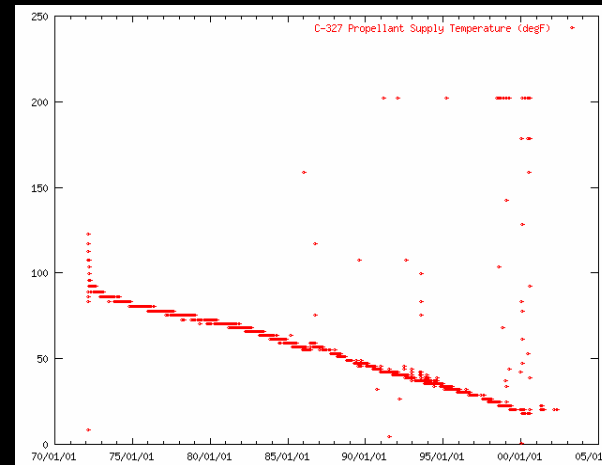
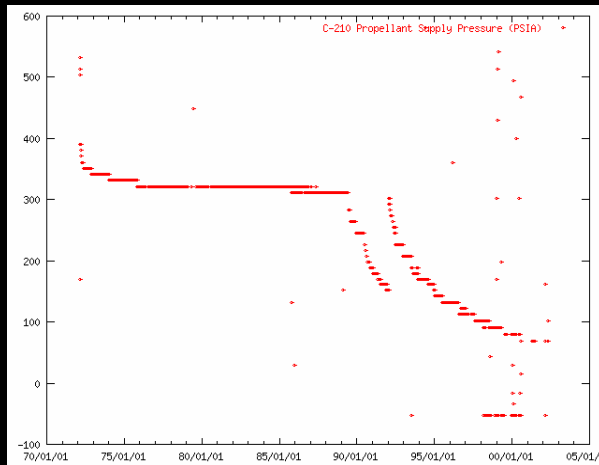
Year	Sample
1972-1975	every 5000 th record
1976-1982	every 1000 th
1983-1989	every 200 th
1990-1997	every 100 th
1998-1999	every 10 th
2000-	all records

C-101 DDTULV	C-102 DDTUMV	C-103 DDTUHV	C-105 PRTG2I	C-106 PBATV	C-107 PBUSEV
C-109 PBCHGI	C-110 PRTG1V	C-111 RRACAGCM	C-113 PRTG4V	C-114 PRTG3I	C-115 PBATI
C-117 PTRFAV	C-118 PTRFBV	C-119 PBUSV	C-121 RRBCAGCM	C-122 PSHNTI	C-123 PRTG4I

Internet

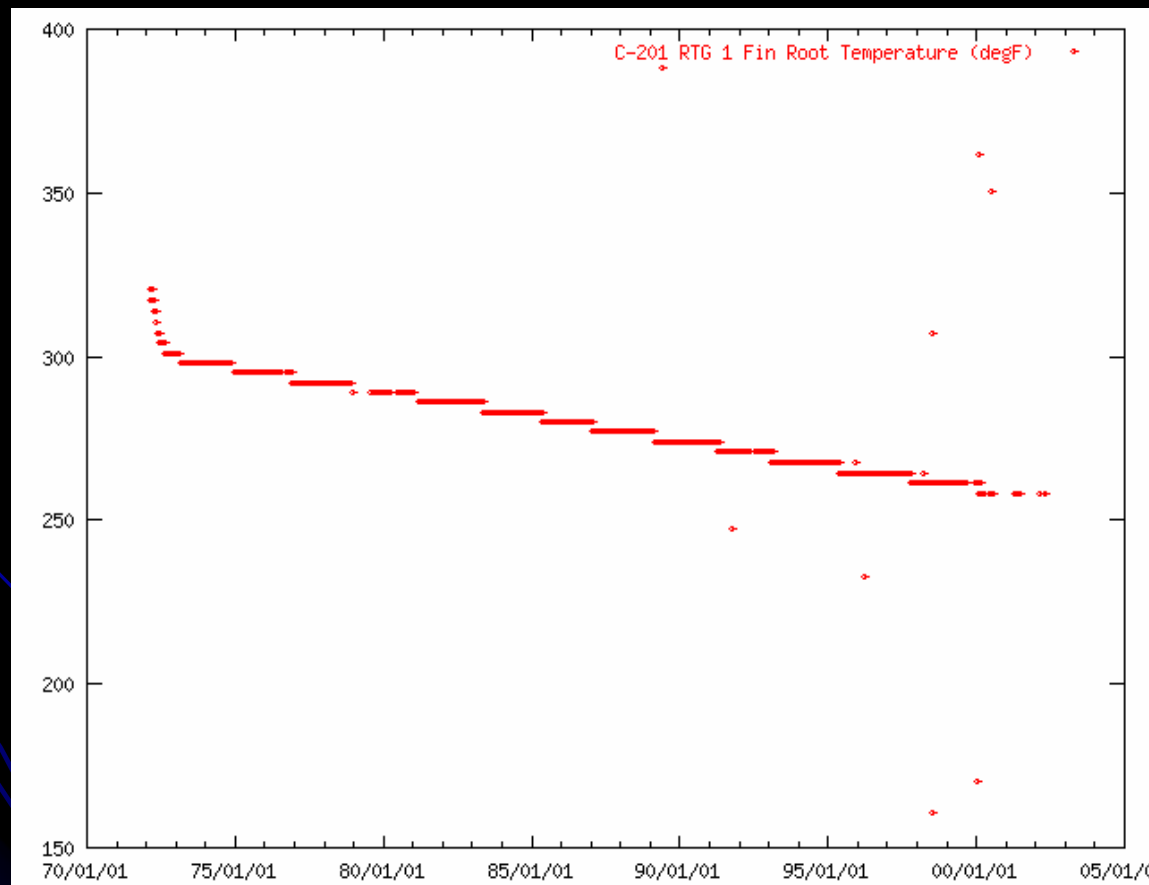
Interesting observations

- C-210 (APROPP) and C-327 (APROPT)
why so different for Pioneers 10 & 11?



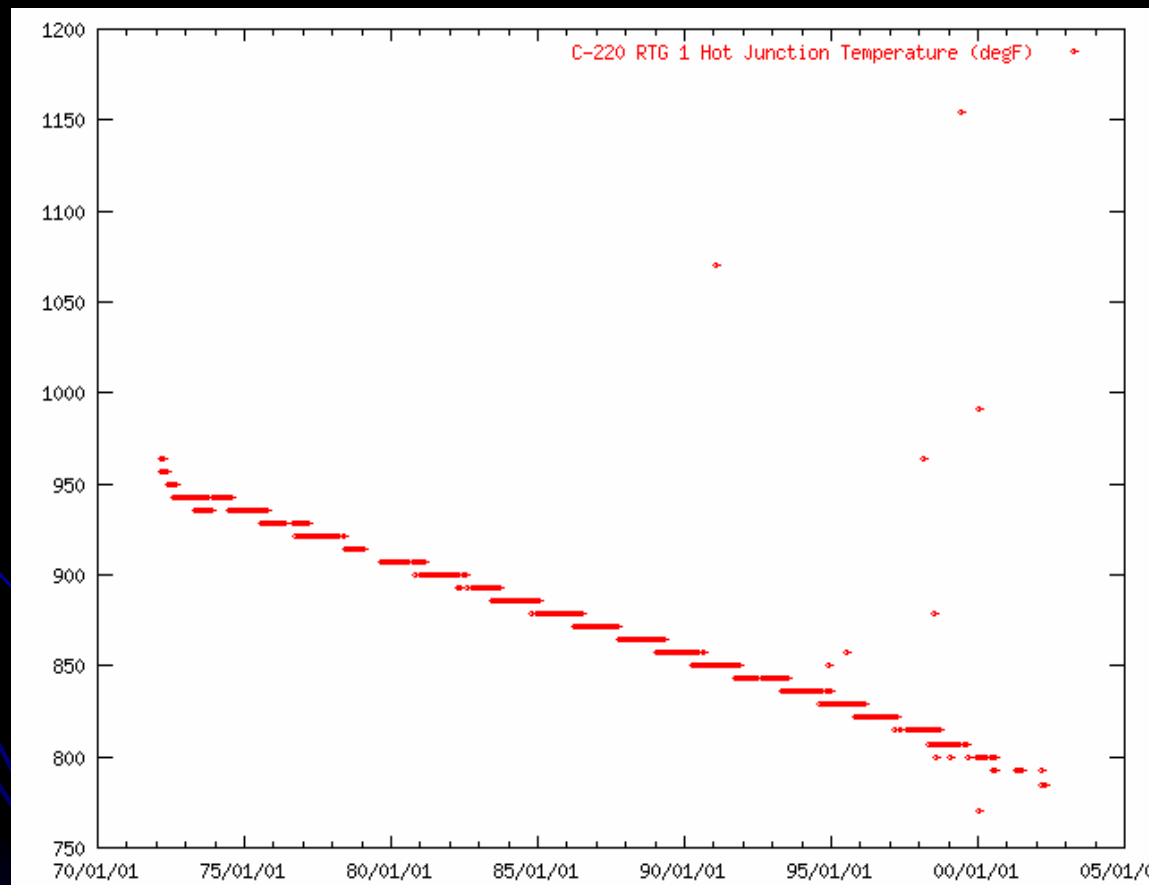
Interesting observations

- C-201..C-204 (PRTG_nFRT): consistent with ^{238}Pu decay



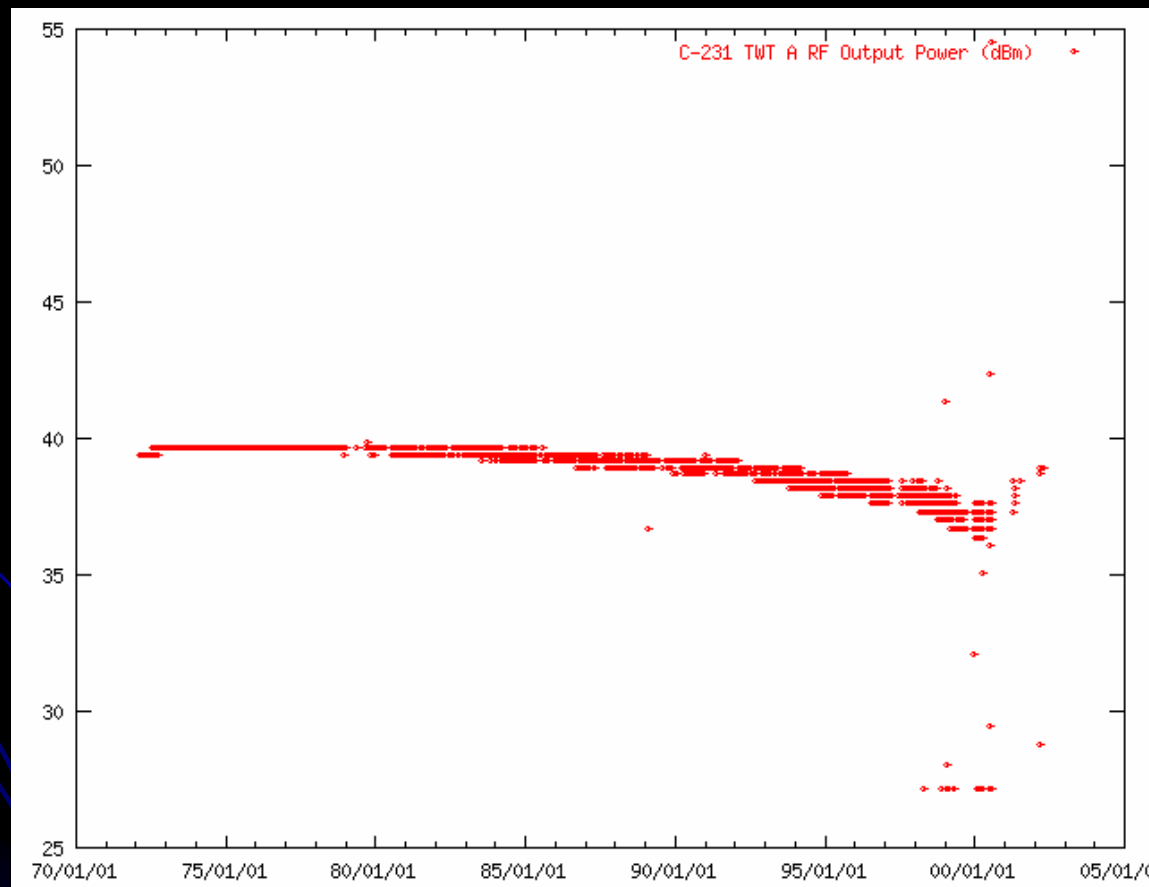
Interesting observations

- C-217-C-220 (PRTG_nHJT): decay much faster. Sensor degradation?



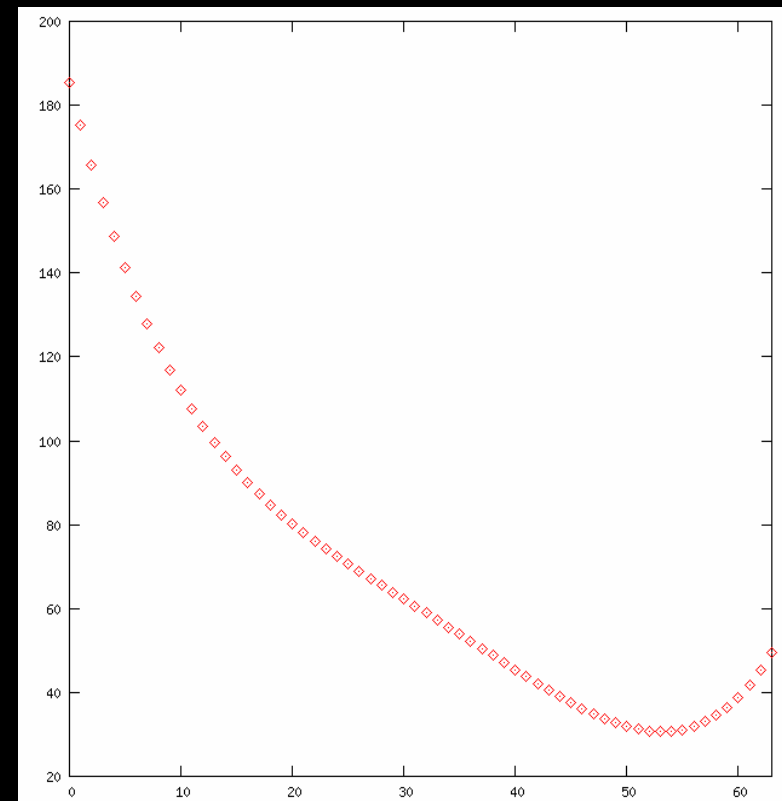
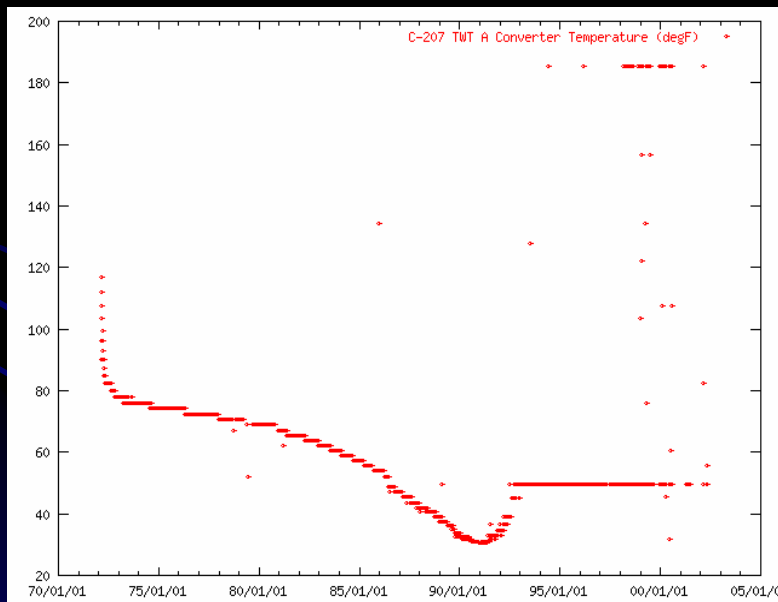
Interesting observations

- Transmitter power not constant.
Confirmed by other readings.



Interpreting the data

- Some values are strange until you look at calibration plots and limits



To Do...

- ✓ Testing and verification
- ✓ Verify calibration values
- ⌚ Verify results against known data sets
- Identify and quantify errors
- ⌚ Develop additional analysis tools
- Improve efficiency and usability