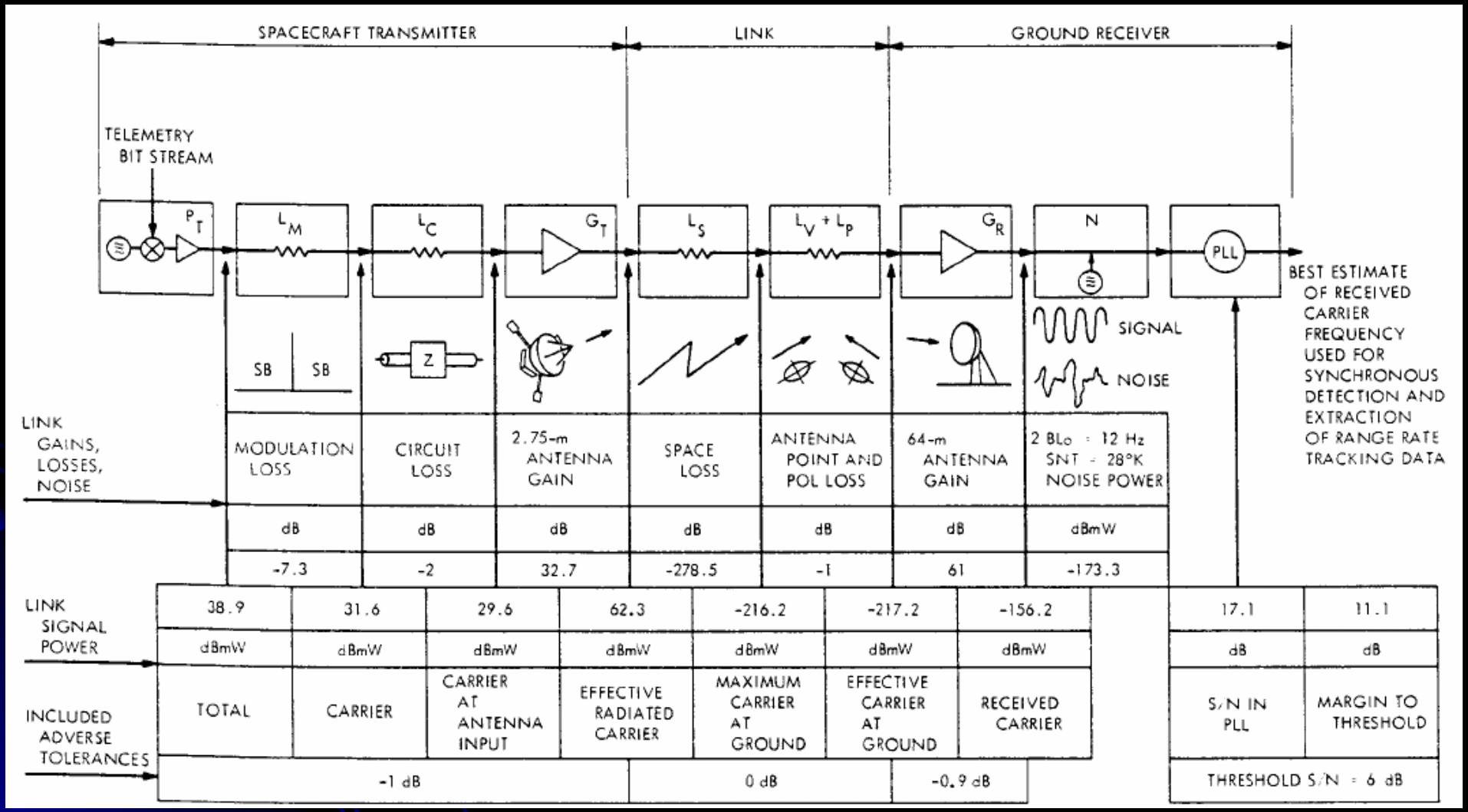
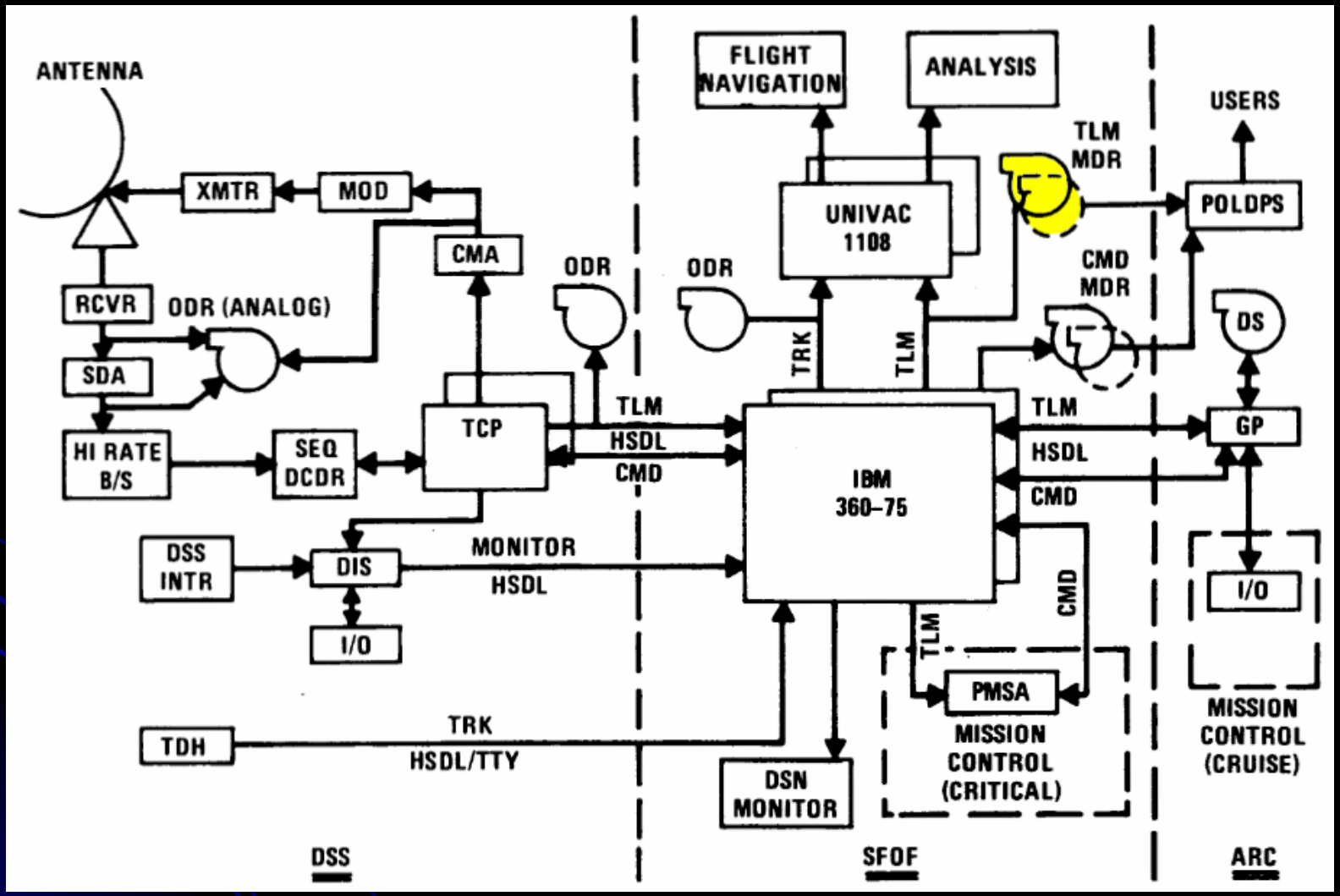
Master Data Records

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);

// ... //
```

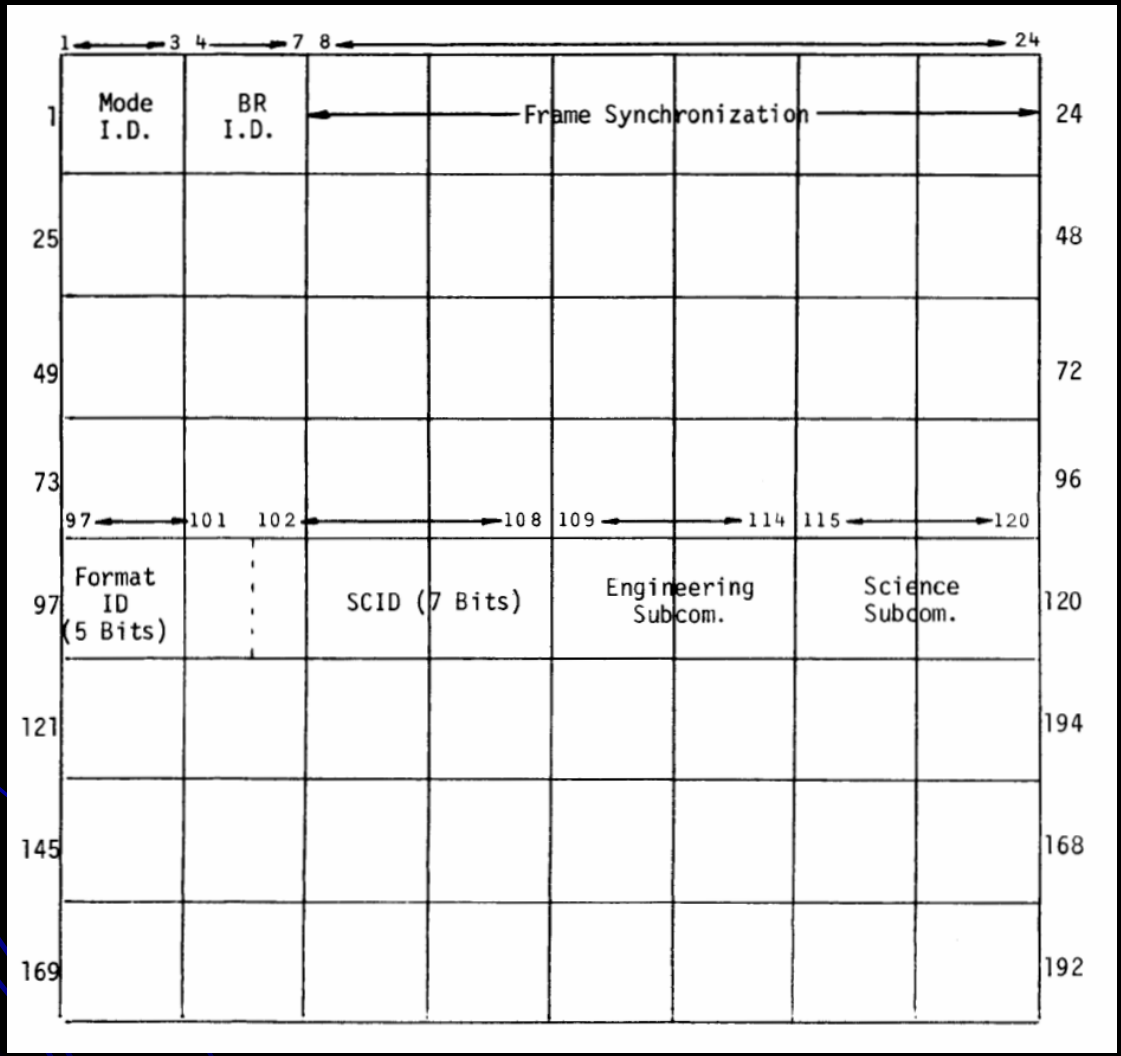
MDR Structure

- MDR Record Structure

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

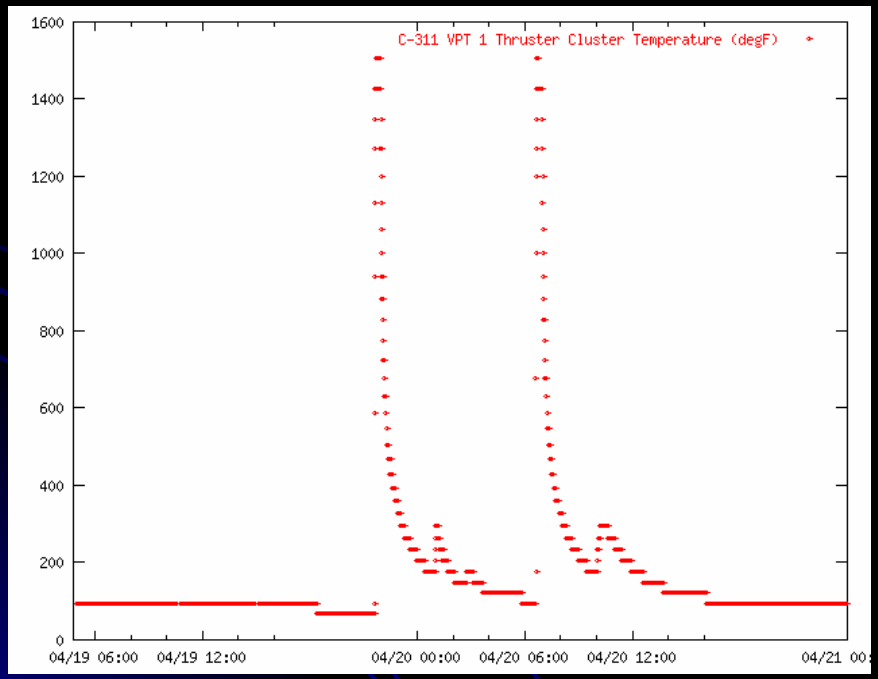
- Data frame formats
  - Scientific (A, B, D): Telemetry in subcomm
  - Accelerated (C1-C4): Telemetry only

Telemetry Frame

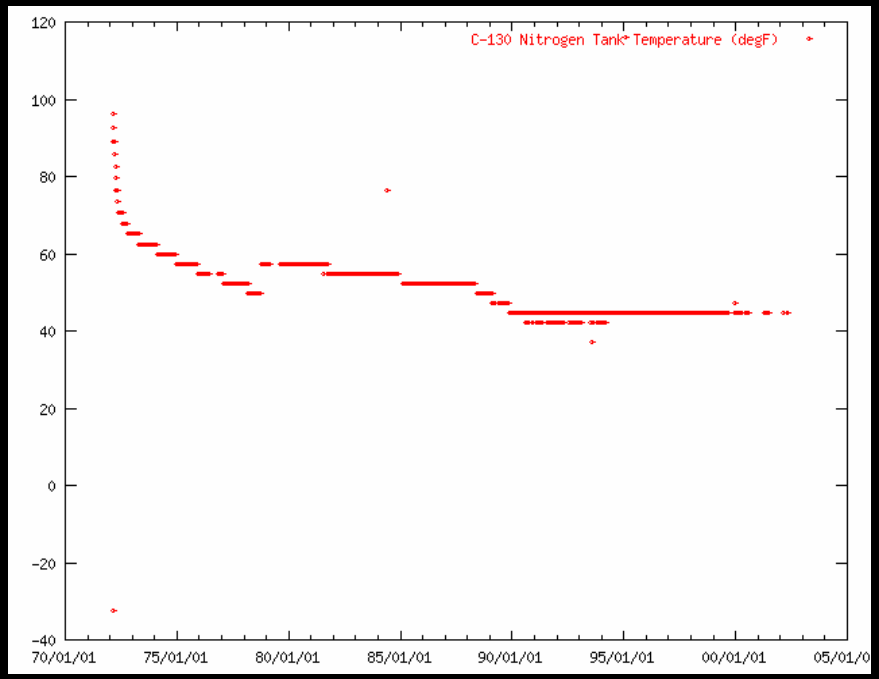


What do we see?

- 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
  $x = a_0 + a_1 b + a_2 b^2 + a_3 b^3 + a_4 b^4 + a_5 b^5$
- 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

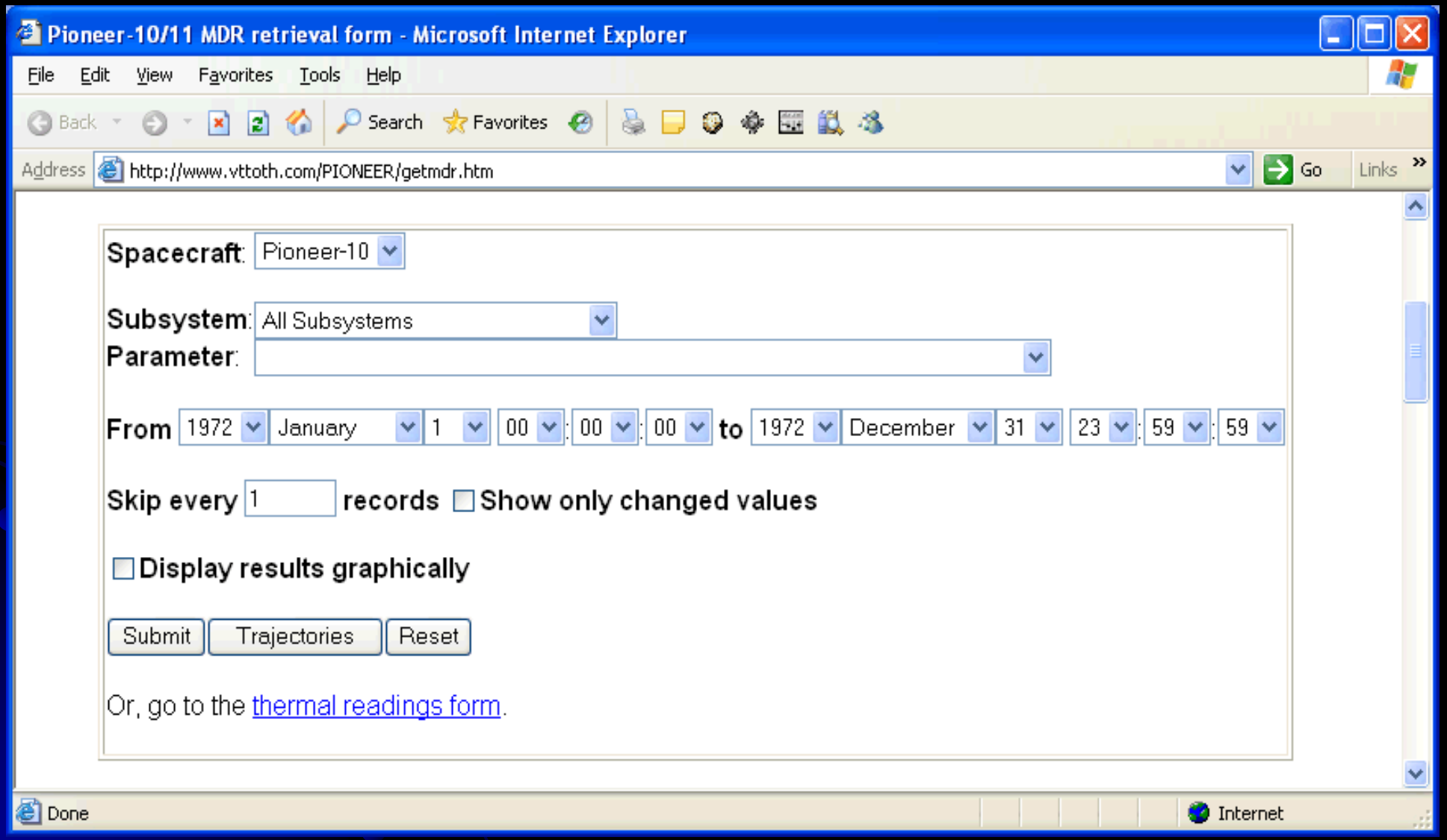
What can we learn?

- 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?

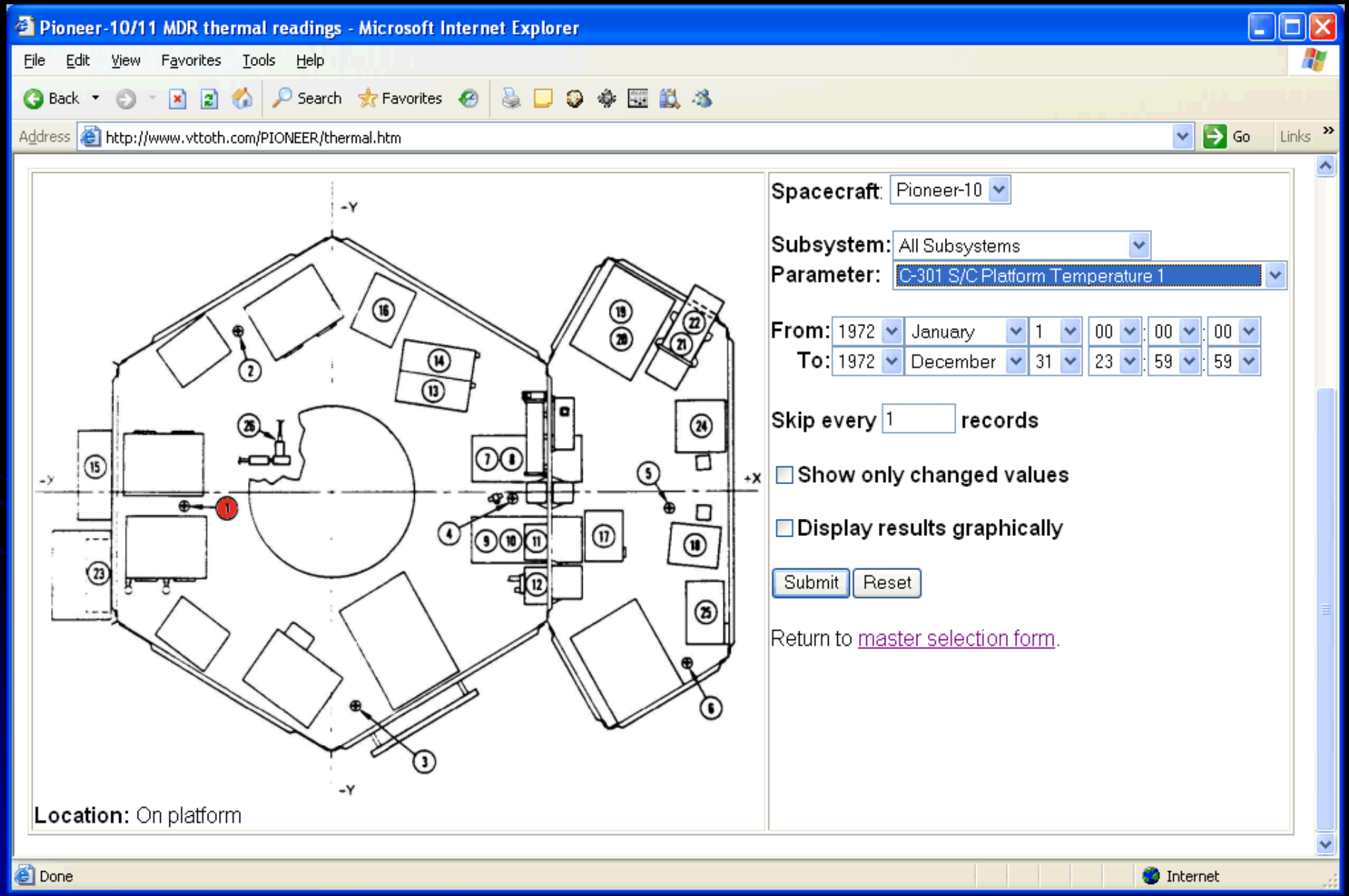
Tools developed

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

Data Extraction Form



Thermal Form



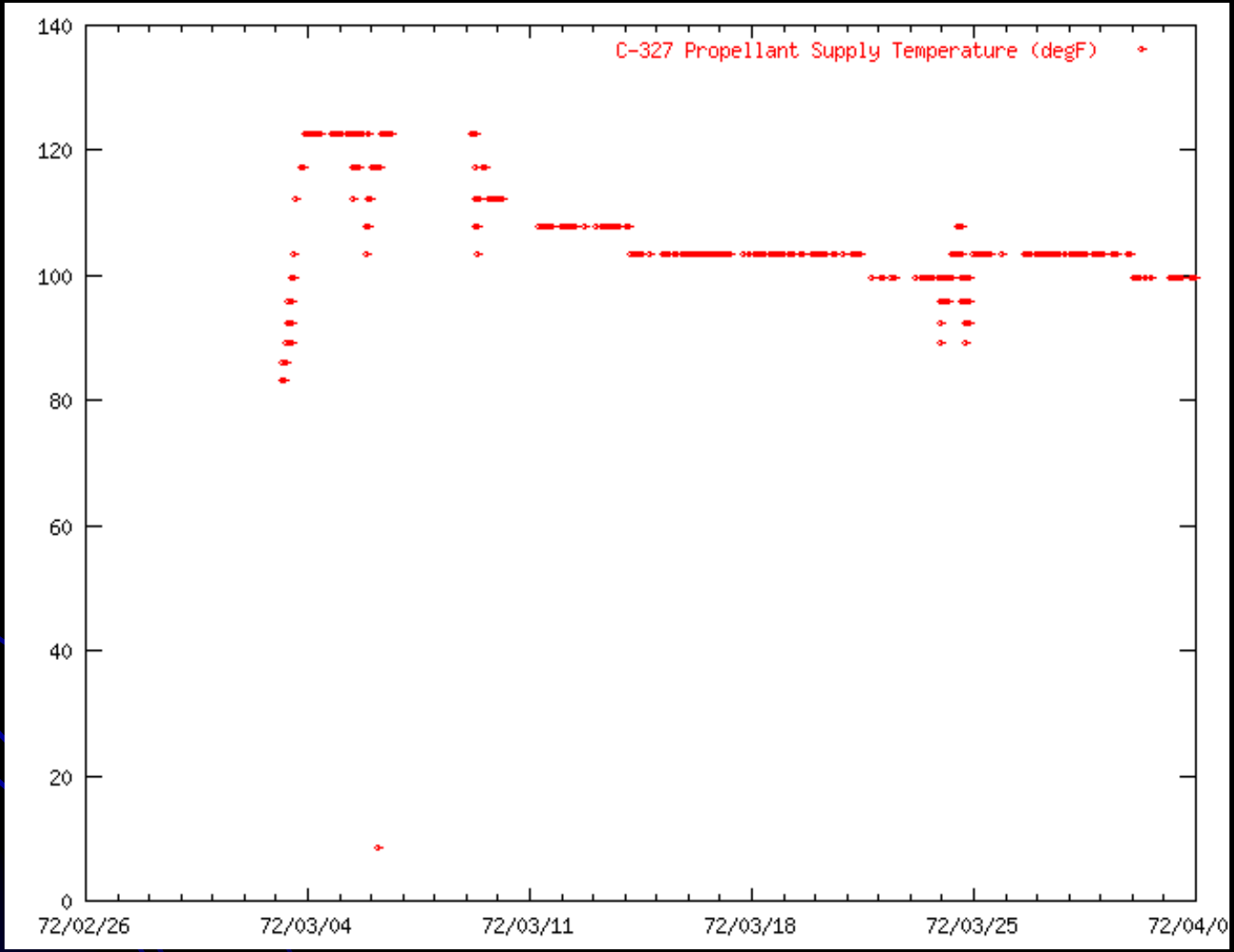
Tab-delimited output

C-220 RTG 1 Hot Junction Temperature (ºF)

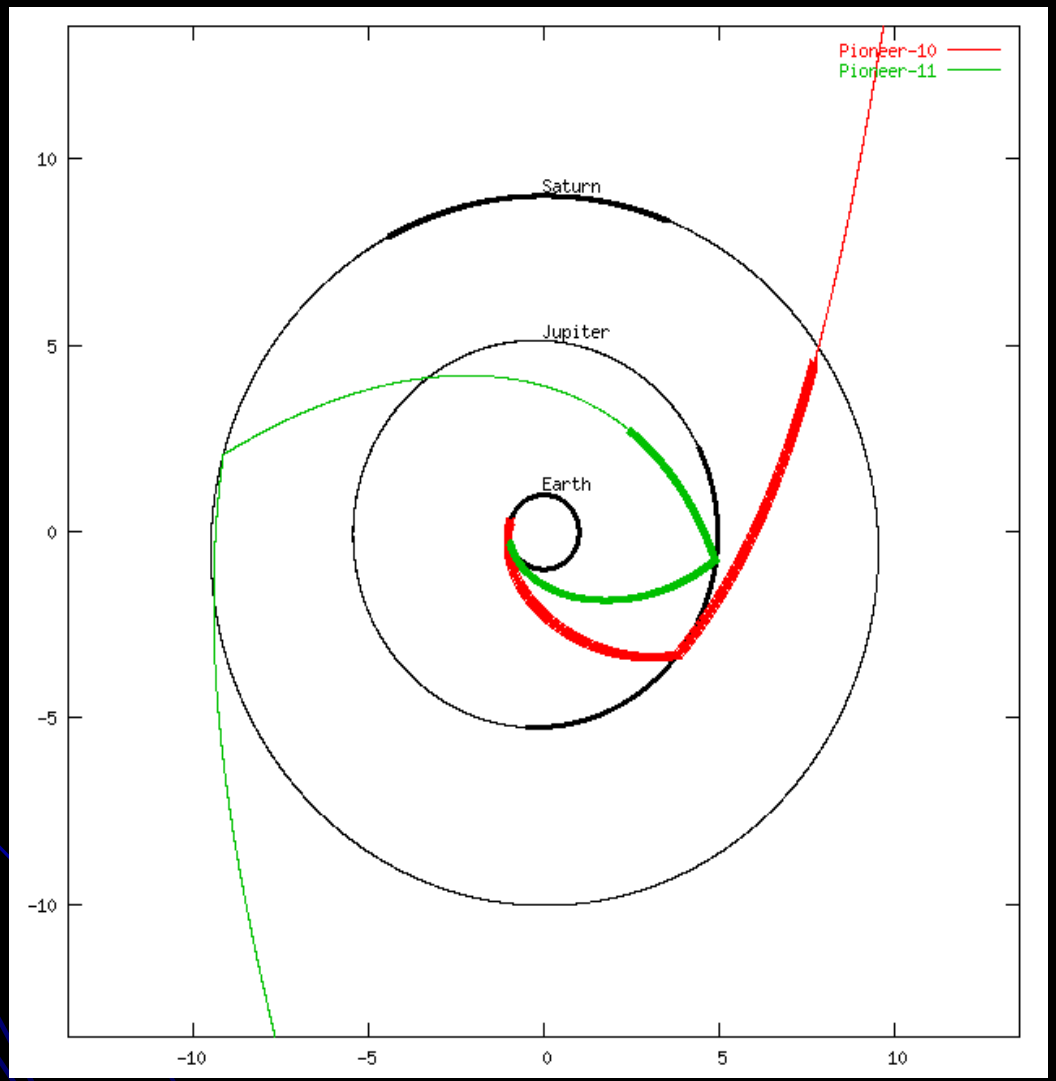
Pathname/Filename	Pos	Timestamp	DQI	SubCom	Binary	Decoded
23P7204/m2372105.mdr	0	72075600.478	3	Y	37	956.346
23P7206/m2372125.mdr	100000	73843275.360	3	Y	37	956.346
23P7224/m2372202.mdr	0	80456400.543	3	Y	38	949.332
23P7228/m2372223.mdr	0	82270800.618	3	Y	38	949.332
23P7232/m2372268.mdr	0	86158801.684	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

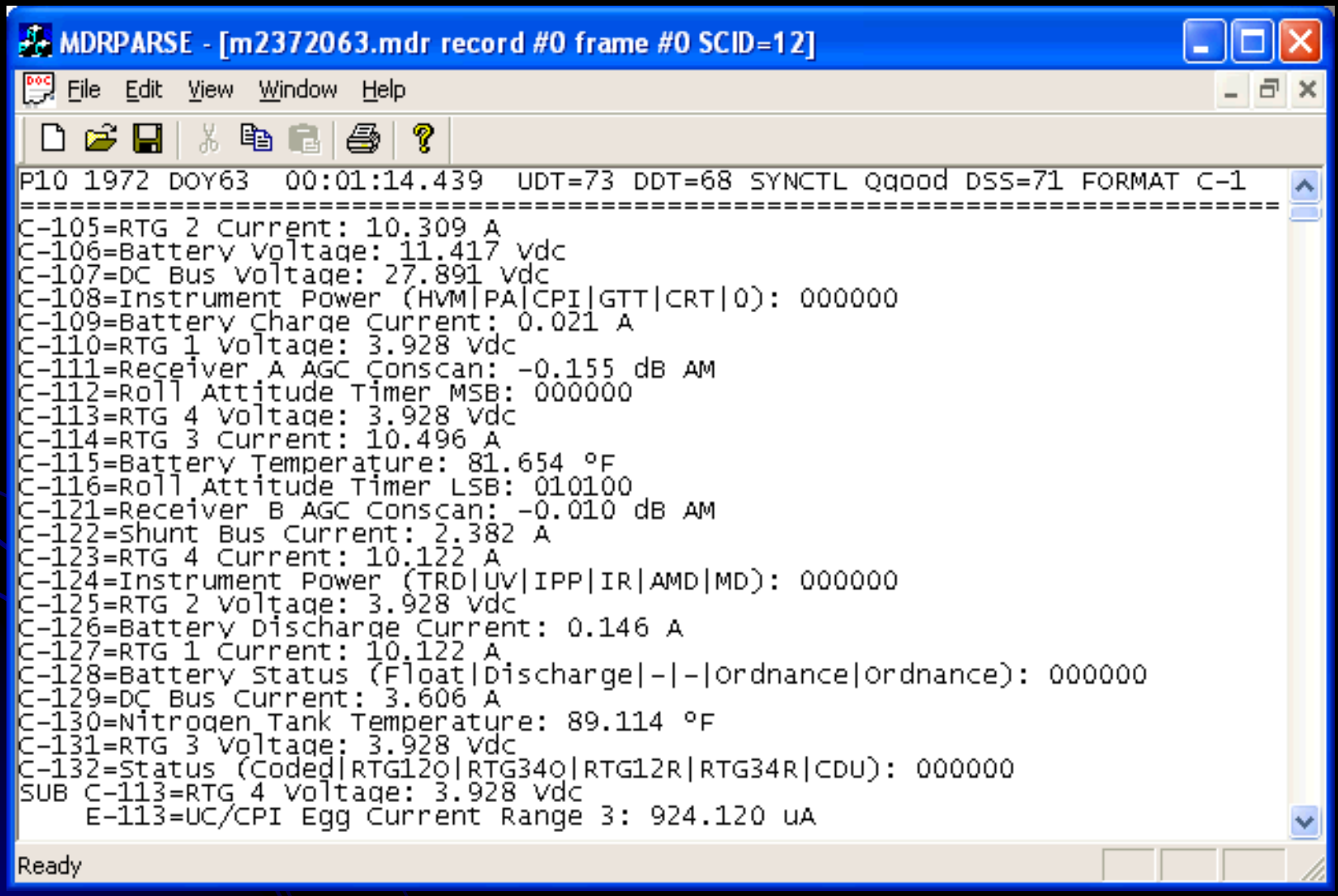
Parameter plots



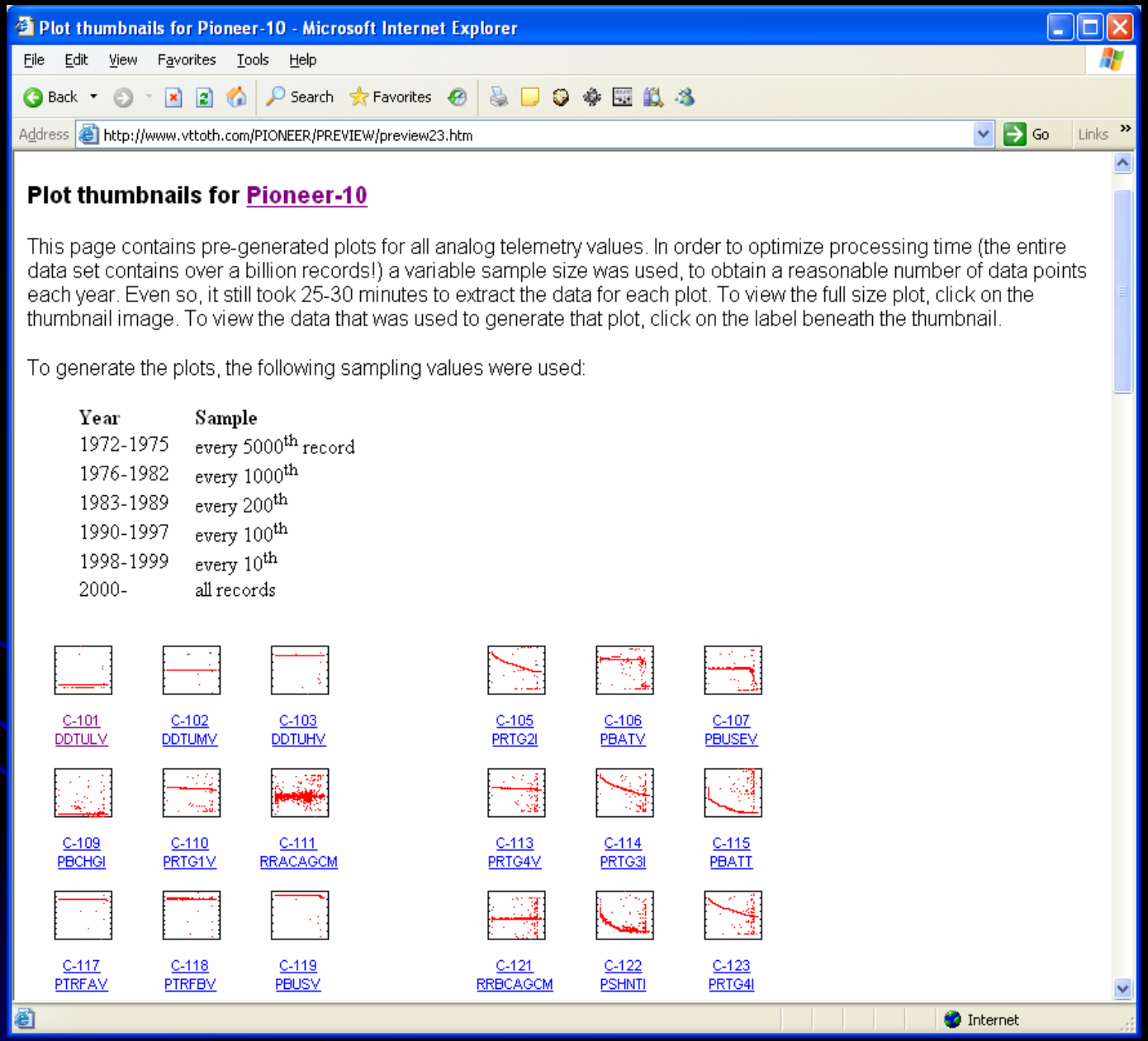
Trajectory plots



Interactive parser

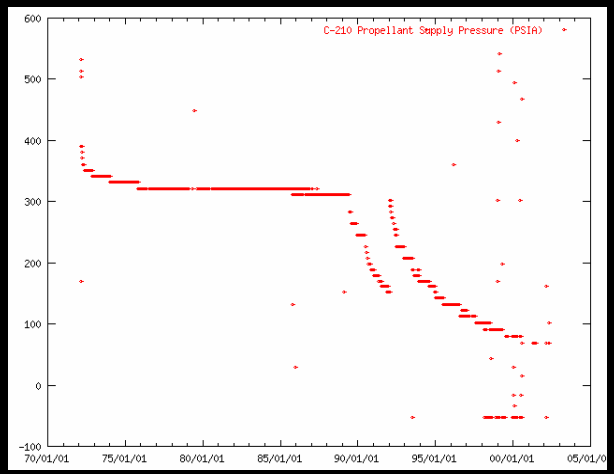


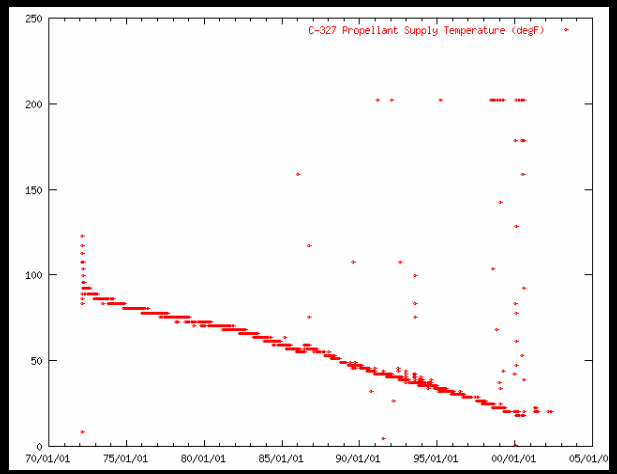
Preview Plots

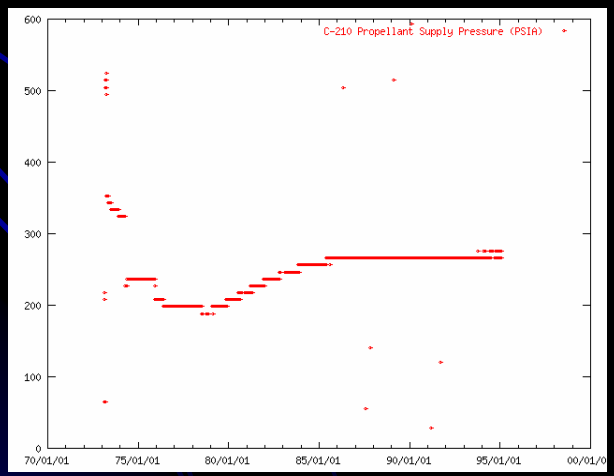


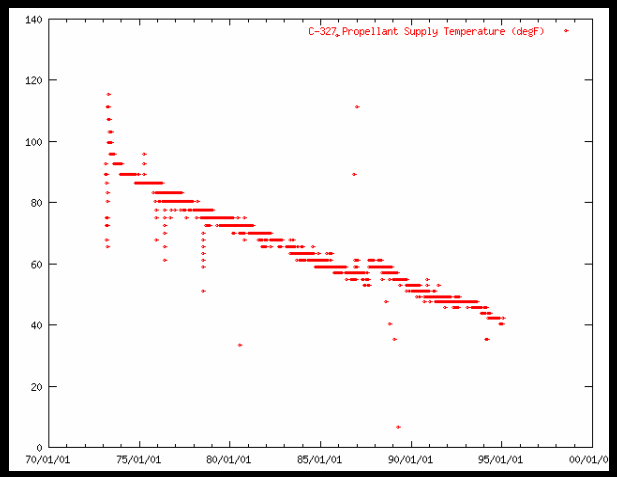
Interesting observations

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



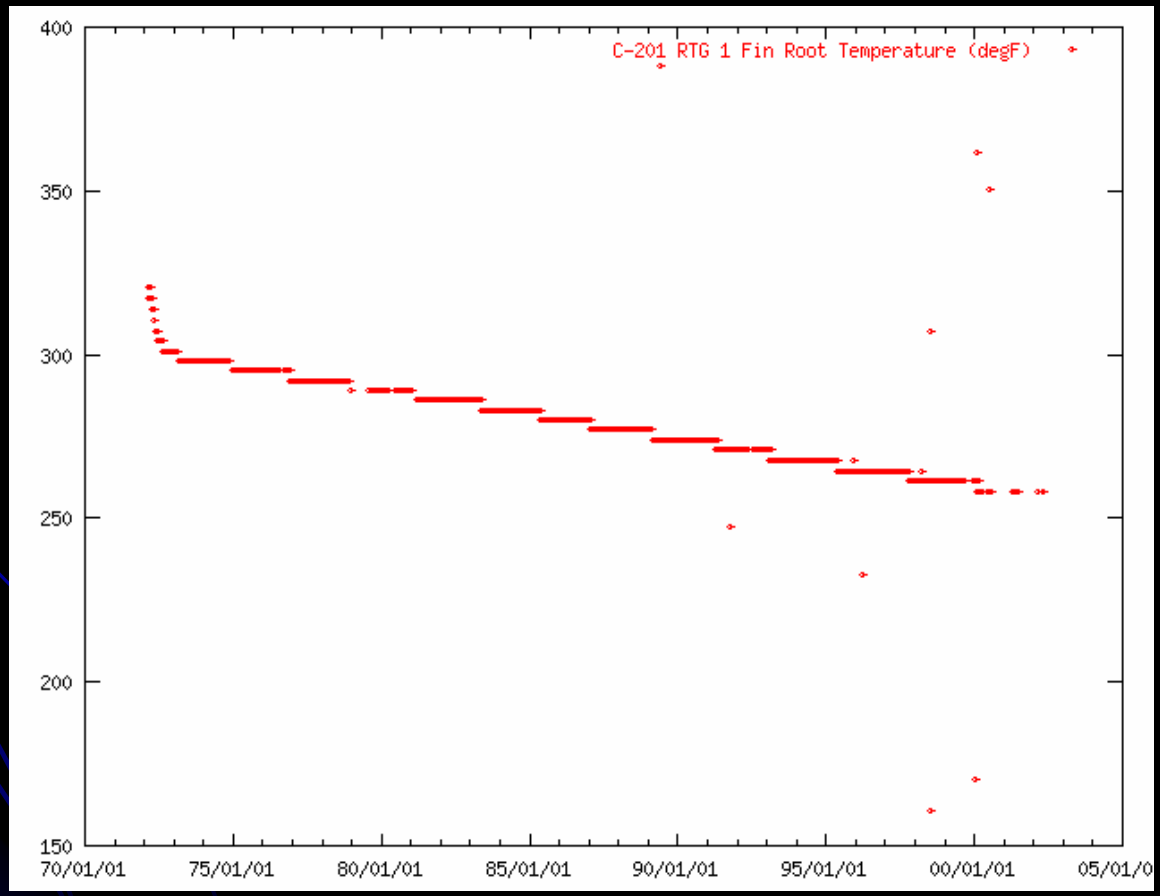






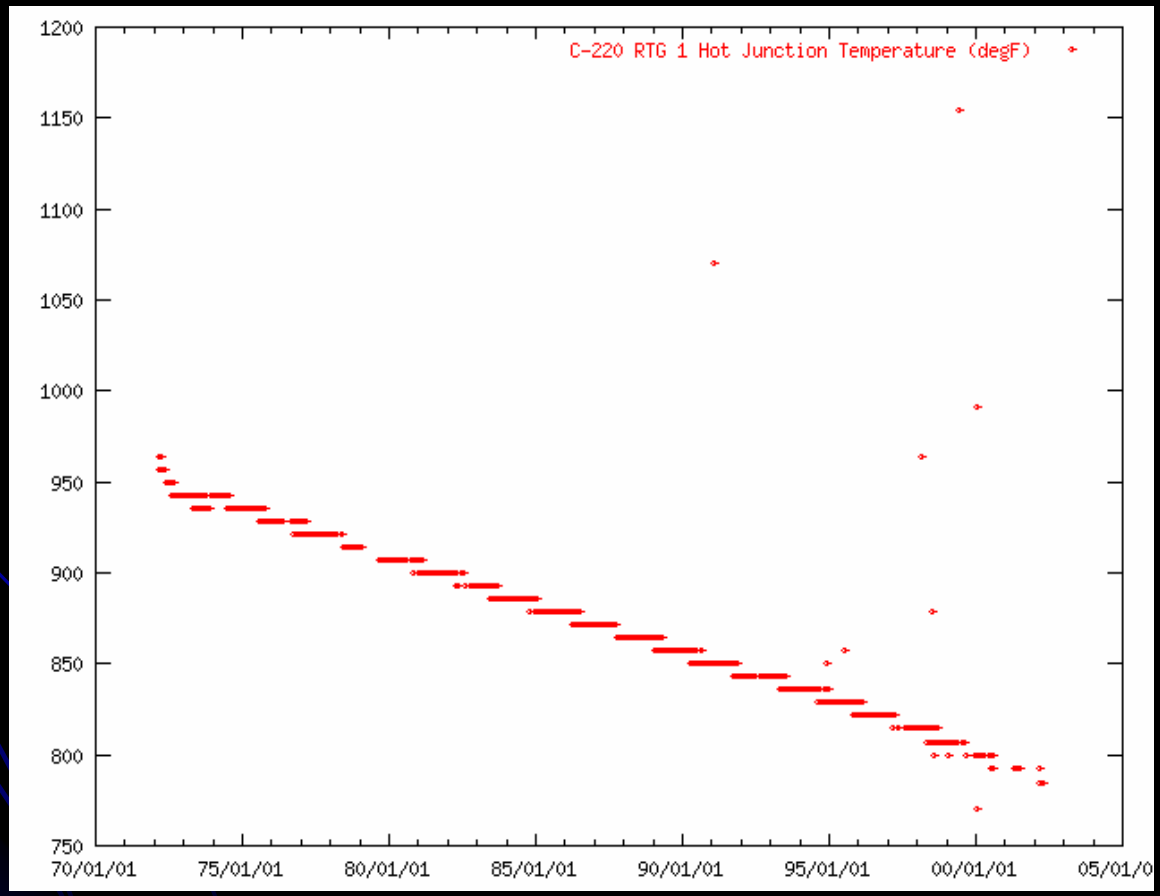
Interesting observations

- C-201..C-204 (PRTG*n*FRT): consistent with ^{238}Pu decay



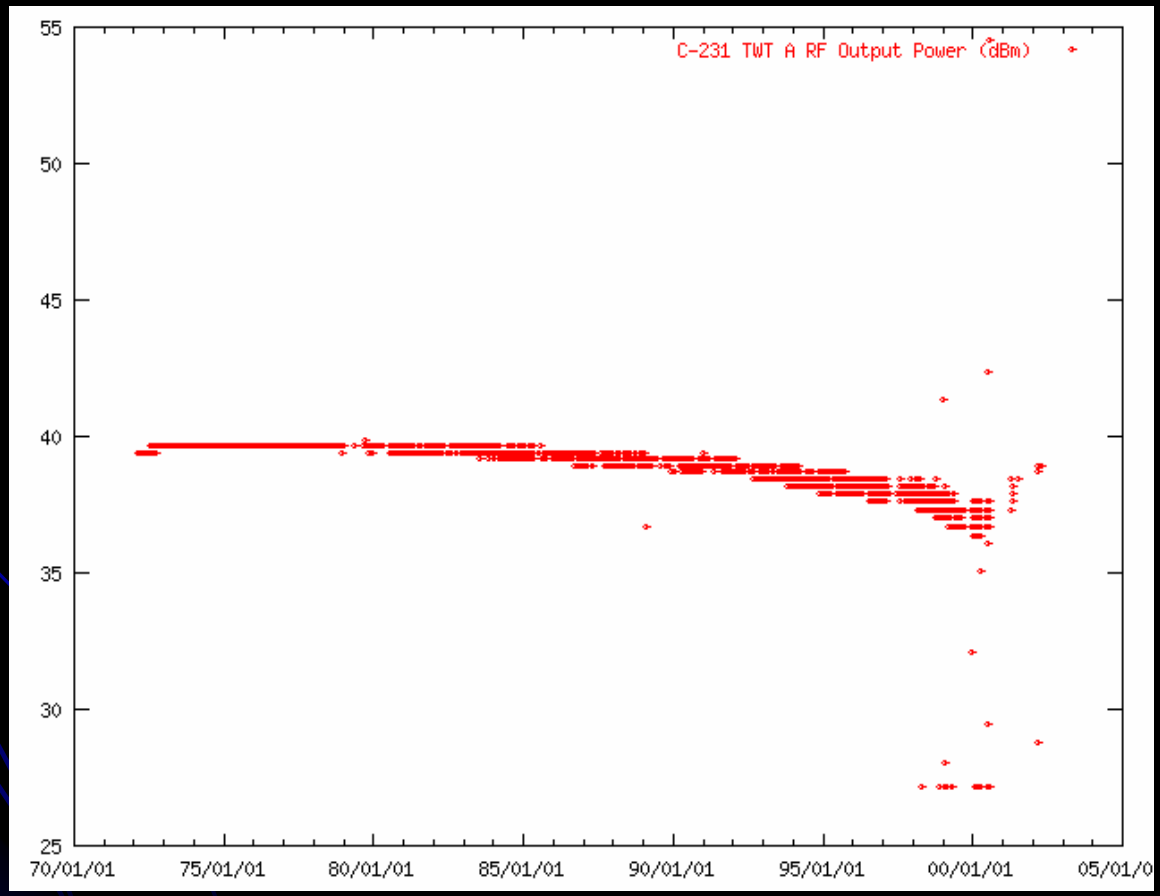
Interesting observations

- C-217-C-220 (PRTG*n*HJT): decay much faster. Sensor degradation?



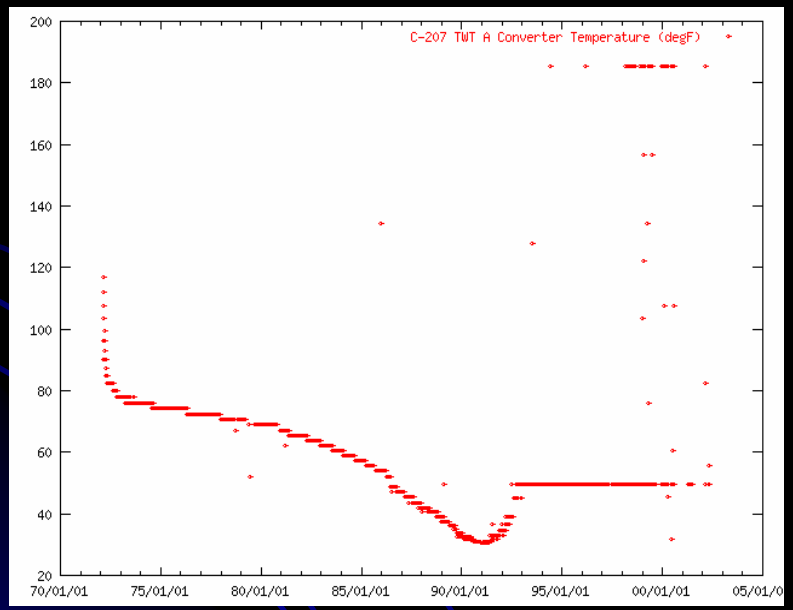
Interesting observations

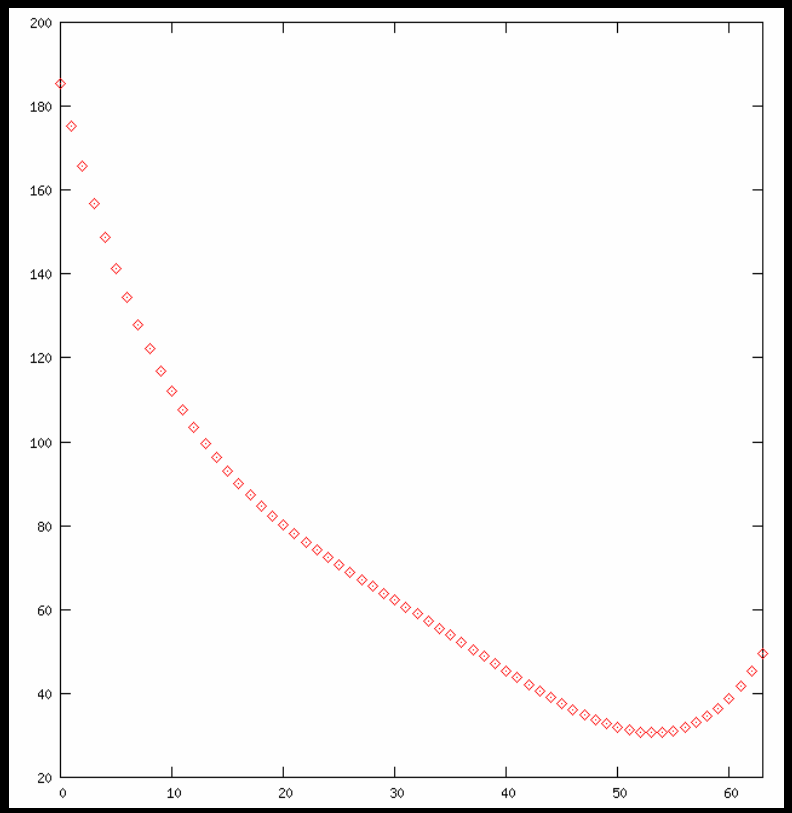
- Transmitter power not constant. Confirmed by other readings.



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