Defence Science Journal, Vol 48, No 2, April 1998, pp. 141-147

Telemetry Data Processing Methodology: An ASLV Experience

R. Varaprasad
Indian Space Research Organisation, Sriharikota - 524 124

ABSTRACT

In any launch vehicle mission, post-flight analysis (PFA) of vehicle telemetry data turns out to be all important, because it helps in evaluating detailed in-flight performance of the various subsystems of the vehicle. An integrated processing methodology was adopted and a generalised software was developed for processing the telemetry data of augmented satellite launch vehicle (ASLV).

INTRODUCTION

Augmented satellite launch vehicle (ASLV) is a technology development rocket of Indian space programme for low orbiting missions. It is a five-stage vehicle with all-solid propellant motors, capable of placing 150 kg satellite into a 400 km near-circular orbit. Telemetry system of ASLV monitors various in-flight performance parameters covering all stages from lift-off to satellite injection, providing valuable data regarding the performance of the launch vehicle during the flight. Instrumentation of the vehicle measures various types of in-flight parameters as given below:

(a) Vehicle parameters, such as acceleration, motor pressures, vibration, acoustics, etc.

(b) Control and guidance parameters, such as rat signals, error signals, etc.

(c) Navigation parameters providing position, velocity, attitudes, etc.

(d) House-keeping data, such as temperature, pressure, strains, voltages, etc.

(e) Even flags, such as stage ignition, stage separation, guidance activation, spacecraft separation, etc.

Vehicle telemetry consists of two pulse code modulation (PCM) systems of 500 kbit/s data rate and another of 70 kbit/s. They are referred to as PCM1, PCM2 and PCM3, respectively. Each chain of PCM telemetry consists of remote units (RUs) connected to a central control unit (CCU). The RUs are located in the core base shroud, the interstages and the equipment bay (EB) of the vehicle. Data acquisition, A/D conversions and transmission of the same to the format control are done in RUs. The CCU contains telemetry format and it commands the RUs as per the format, and generates the frame synchronisation code as well as the frame, IDs. The data received from various RUs are put in proper slots. A 128-byte long frame with 116 channels is selected for ASLV telemetry for PCM chains. A subframe consists of 16 such frames, wherein the frames ID monotonically increases from 0 to 15 (Fig. 1).

The vehicle telemetry parameters are transmitted through three different S-band transmitters. The telemetry network for ASLV

Received 23 August 1996, revised 12 November 1997

	116 TELEMETRY CHANNELS													
						FRAME Id								
	0	12	13	14	15	16	26	30	31	75	76	125	126	127
FRAME 1			CP3	2SM	CP4	0	IP4		CP1	CP4	IP4		IP4	
FRAME 2			CP3		CP4		IP4		CP1	CP4	IP4		IP4	
FRAME 3			CP3		CP4	2	IP4	ET2	CP1	CP4	IP4		IP4	
FRAME 4			CP3		CP4	3	IP4	EZ2	CP1	CP4	IP4		IP4	
FRAME 5			CP3	2SM	CP4	4	IP4		CP1	CP4	IP4		IP4	
FRAME 6			CP3		CP4	5	IP4		CP1	CP4	IP4		IP4	
FRAME 7			CP3		CP4	6	IP4	EP2	CP1	CP4	IP4		IP4	
FRAME 8			CP3		CP4	7	IP4		CP1	CP4	IP4		IP4	
FRAME 9			CP3	2SM	CP4	8	IP4		CP1	CP4	IP4		IP4	
FRAME 10			CP3		CP4	9	IP4		CP1	CP4	IP4		IP4	
FRAME 11			CP3		CP4	10	IP4	ET2	CP1	CP4	IP4		IP4	
FRAME 12			CP3		CP4	11	IP4	EZ2	CP1	CP4	IP4		IP4	
FRAME 13			CP3	2SM	CP4	12	IP4		CP1	CP4	IP4		IP4	
FRAME 14			CP3		CP4	13	IP4		CP1	CP4	IP4		IP4	
FRAME 15			CP3		CP4	14	IP4	EP2	CP1	CP4	IP4		IP4	

Figure 1. A typical telemetry subframe

mission consists of ground stations at Sriharikota, Thiruvananthapuram and Car Nicobar. Car Nicobar is the down-range station and Thiruvananthapuram, the space diversity station. A space diversity station is planned to compensate for the loss of a signal in the SHAR stations due to flame attenuations.

2. TELEMETRY DATA PROCESSING

The requirements in the pre-flight and post-flight scenario (Fig. 2) are as follows:

(a) Limit-checking of selected static PCM parameter during electrical and mechanical integration of launch vehicles helps in the study of their dynamic behaviour.

(b) Creation of valid raw data files

(c) Processing of three-stream PCM data from all ISRO telemetry network stations (TNS) consists of: (i) stripping and processing in-flight vehicle pa rameters, (ii) event status monitoring, and (iii) navigation guidance and control parameters (NGCP) processing, and

(d) Presentation of selected parameters.

3. PROCESSING METHODOLOGY

A two-layerd processing methodology[1] is adopted for meeting the various requirements of the vehicle subsystem specialists. A centralised stripping and preprocessing methodology is adopted at the top to expedite the generation of valid raw data files after acquiring the data from geographically distributed TNS and to verify the conversion tables. Afterwards, a distributed PC-base processing methodology, at a level local to the end users, is adopted to facilitate faster user interaction with the data and to effectively meet their specific requirements.

3.1 Valid Raw Data Acquisition

Data received at TNS is recorded on analog tapes and is passed through the PCM synchroniser, wherein formatting of the data together with tagging of universal time (UT) is done. The data is copied onto digital tape. A quick scanning is

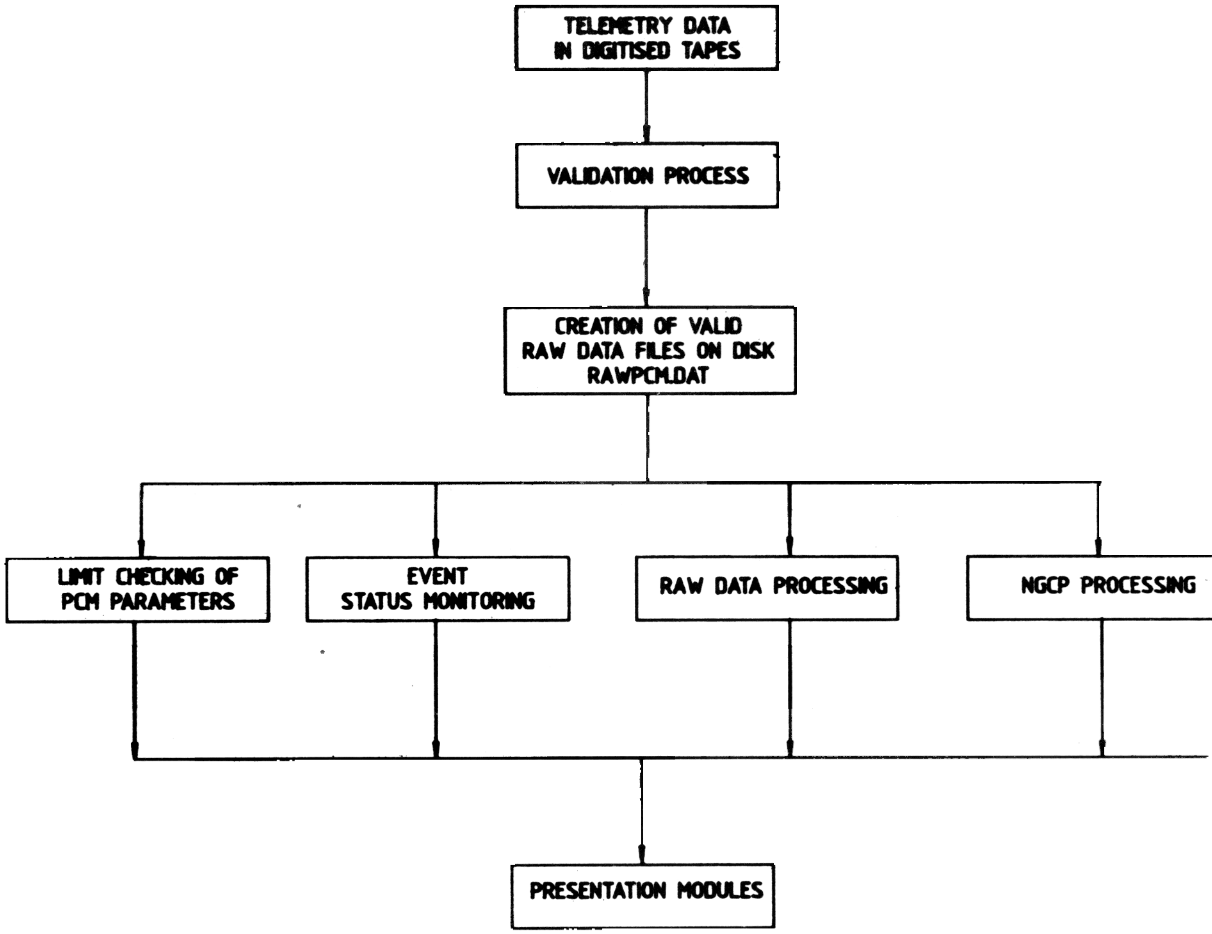

Figure 2. Schematic diagram for telemetry data processing - ASLV mission

conducted to verify the validity of the digitisation process by recording the invalid frame sync patterns, invalid IDs as well as time jumps. Depending on the number of wrong frame sync patterns and invalid IDs a decision is taken whether to repeat the digitisation process or not. Once the scanning is through, valid raw data file 'RAWPCM.DAT' is created for each PCM chain from each station after tagging countup time to each valid frame.

3.2 Data Stripping & Preprocessing Methodology

The key document 'measurement plan'[2] is the first basic input to telemetry data processing. It contains the telemetry channel allocation and format details of all analog and digital PCM parameters as well as NGCP. By their very nature, the telemetry parameters classify themselves as supercommuted parameters, normal parameters and subcommuted parameters. Supercommuted parameter are those which occur more than once in every frame at requisite channels. Normal parameters are those which occur once in every frame, wheras the subcommuted parameters occur only in certain frames in a subframe. Table 1 gives a set of typical signals, their corresponding channels and the type of parameters.

There are basically four different strategies for stripping and preprocessing the telemetry data. These strategies evolve from two different approaches applied to two different areas in TDP. Two different approaches can be adopted for selecting the basic input data for the processing cycle. The basic input can be either a frame or a subframe. The former ensures that all data received

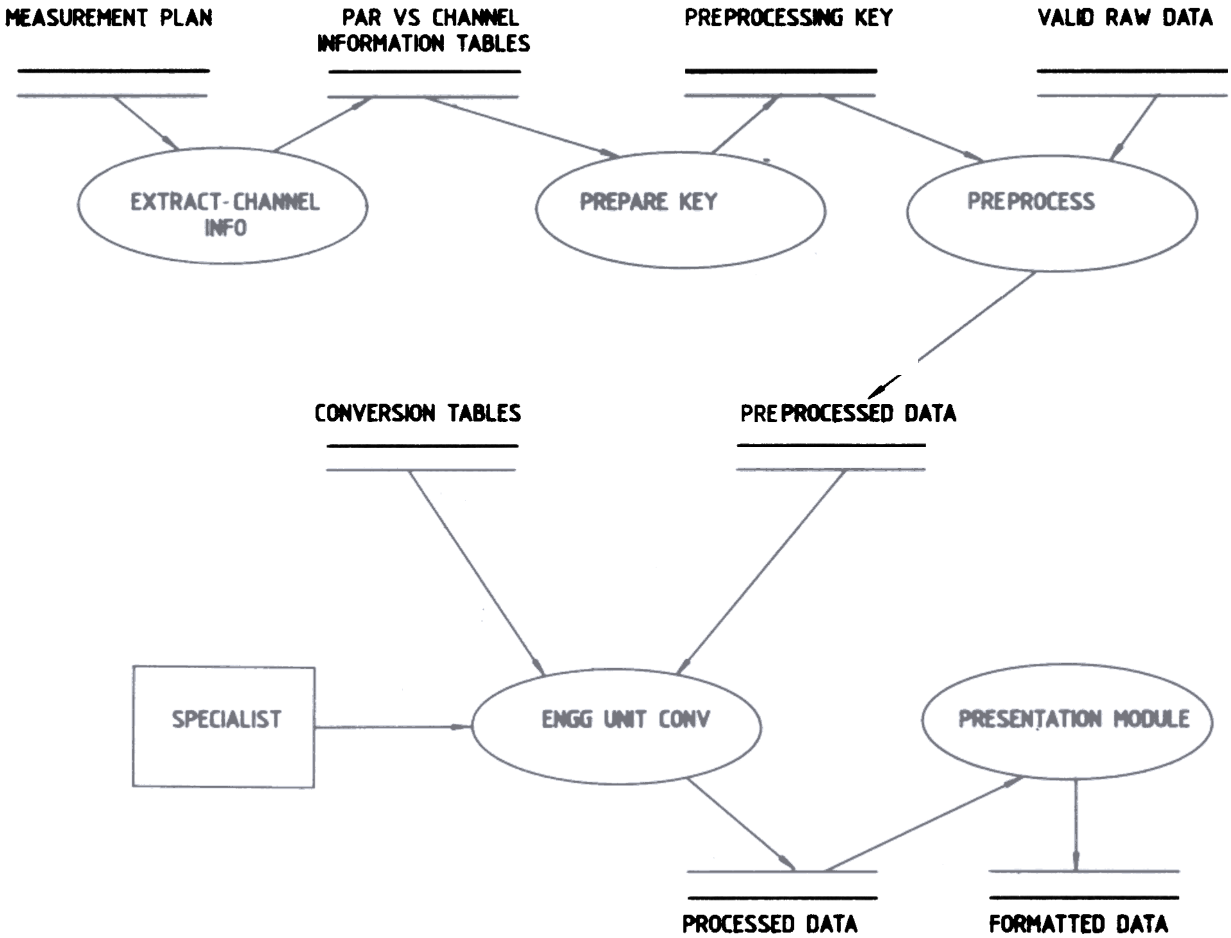

Figure 3. Context diagram for telemetry data processing

at TNS is processed, whereas the latter requires that all parameters telemetered through a PCM chain are coming at least once. The advantage in the latter is that parameters of similar nature can be grouped, thereby offering more user-friendliness. But the underlying disadvantage is that not all data received at TNS is considered for processing. Another area where two different approaches can be implemented is in extracting samples from valid raw data w.r.t. time. Sampling time is defined as the countup time at which a particular sample is collected on board. The first approach is based on treating time as an independent variable and incrementing it appropriately while picking up samples. The second approach is to collect all samples of the parameter and to calculate the time of sampling. The advantage of the first approach is that we have total control on the timings, which facilitates grouping of the parameters irrespective of their sampling rates and sampling times. But the disadvantage lurking behind is that the time reference is not the true sampling time. The second disadvantage is that the same sample may be picked up again and again and some samples may not be picked up at all. The advantage of the second approach is that it overcomes all the disadvantages of the first. But the disadvantage is that grouping of parameters may be restricted by the accuracy needed in printing times. For example, there may be two parameters with the same sampling rate, but it may not be feasible to combine them, because their sampling times are different.

In all, four strategies are evolved out of these two approaches:

Table 1. Data requirements from a typical station

Signal	Legnd	Channel	Type of signal
Error signal ephi			Sub-commuted
Error signal etheta	ET2	30.3,30.11	Sub-commuted
Error signal epsi	EZ2	30.4,30.12	Sub-commuted
S1 motor head cap pressure	CP1	31	Normal
S3 motor head cap pressure	CP3	13	Normal
S2 separation monitor	2SM	14.1,14.5,14.9, 14.13	Sub-commuted
S4 motor head cap pressure	CP4	15,75	Super-commuted
S4 motor ign. pressure	IP4	6,36,66,96	Super-commuted

(a) Frame selected as a basic input and samples picked up as a function of time.

(b) Subframe selected as the basic input and samples picked up as a function of time.

(c) Frame selected as basic input and time calculated as a function of samples picked up.

(d) Subframe selected as basic input and time calculated as a function of samples picked up.

Out of these four strategies, the first one cannot be used, since samples of all parameters are not available in a frame (Fig.1). On the other hand, all parameters, whether supercommuted or normal, will be tagged with the same reference time, which in reality is not so. For example, a supercommuted parameter, such as IP4 is sampled thrice in a frame and a normal parameter CP3 will have the same reference time (Table 1). The second strategy of selecting a subframe as a basic input and samples picked up as a function of time is suited for a quick-look post-flight analysis QPFA. All parameters of interest sampled once and tagged with the reference time of. the first frame. This strategy is highly useful, when a quick glance at the performance of various subsystems is needed. The third strategy of selecting a frame as a basic input and time calculated as a function of the samples picked up is apt for a detailed post-flight analysis (DPFA), because a thorough processing of the data with true reference time is conducted. The time of each sample of the parameter is calculated as:

$$T = \text{Reference time of the frame} + \Delta T$$

$$\Delta T = \text{Time interval of frame}/ 218 * \text{parameter channel}$$

Like the third strategy, the fourth one is also suited for DPFA. But the lacuna is that unlocks and missing samples in between make a subframe invalid, resulting in all data not being processed. For these reasons, the third strategy is adopted for DPFA of ASLV-D3 mission. The stripper module EXTRACT-CHANNEL-INFO reads the measurement plan to extract the channel information to create parameter *vs* channel information files, which are input to preprocessing software. The channel information files contain the file names, group of parameters and their channel allocation details. The second basic input to the preprocessing software is the valid raw data file RAWPCM.DAT, which consists of the time-tagged records of 116 bytes.

3.3 Functional Description of Processing Modules

The telemetry parameter stripping and processing s/w consists of following s/w modules:

(a) PREPARE-KEY

(b) PREPROCESS

(c) ENGG-UNIT-CONV

PREPARE-KEY creates key information and data files (group files) with header information (Fig. 3). This key information helps in mapping the data from raw data files to the respective group files, while the header file helps in identifying the data sets. Input to PREPARE-KEY is the parameter *vs* channel information file of a group of parameters. Grouping of parameters is based on the following guidelines:

- Parameters in a file should have the same sampling rates.

- Samples of the parameter should come in the same frame.
- Parameters in a group are an ordered set.

The output of the above tasks is input to the next module PREPROCESS. This is basically an I/O bound job in that it strips parameters of interest from the raw data files, mirror-images, preprocesses (voltage conversion) and maps the data onto designated output files. As READ/WRITE operations consume a sizeable CPU time, a buffered I/O technique is used, wherein a fixed length buffer is created for each group file. After each READ operation, data are preprocessed, tagged with countup time and written onto the buffer. After the buffer of a particular group files is full, then only a WRITE operation is executed to dump the data in the buffer onto that particular group file. In this way the number of READ/WRITE operations is drastically reduced, making the stripping software faster. The output are the group files containing the header information and time-tagged telemetry parameter values in hexa decimal (HEX) form. Until now, a centralised processing methodology is followed, so that valid raw data files along with the conversion table can be provided to the end users. Now, a distributed PC-based processing methodology is adopted to meet the varied requirements of the end users at a faster pace. The third module, ENGG-UNIT-CONV, is the conversion module which, using the conversion table, converts the preprocessed parameter values of a group file into the corresponding engineering units. The module is developed in C and is implementable on a PC. The conversion module and the validated conversion tables and group files are provided to the end users for detailed processing of the PCM telemetry parameters. PRESENTATION Module provides for printing/plotting of the parameters of interest in the required format.

4. RESULTS

DPFA of the telemetry data of ASLV-D3 mission was planned and carried out on VAX-11/785 systems of SHAR, cyber system of VSSC and PCs. Voluminous quality telemetry data of 250 MB was received at all ISRO TNS from lift-off of the vehicle to satellite injection. The valid raw data were preprocessed and distributed to the end users for further processing. The above methodology was scrupulously implemented and requirements of all end users were satisfactorily met.

5. CONCLUSION

An integrated telemetry data processing methodology as implemented for ASLV missions has been described. This methodology has successfully met the specific requirements of various end users. It is felt that a table-driven generalised software can meet the telemetry data processing requirements of any ISRO launch vehicle mission.

REFERENCES

1. Hussain, S.F.; Babumohanan, K.V; Varaprasad, R. Design document of telemetry data processing for ASLV-D3 mission. Report No. TR-03-82-92.

2. Babumohanan, K.V.; Santhi, N. & Ramaratnam, S. Vehicle telemetry data handling plan, real-time processing details for ASLV-D3 mission. Report No. VSSC/ASLV/TR/182/91.

Contributor

R Varaprasad obtained his MSc in Physics from Andhra University. He joined Indian Space Research Organisation (ISRO) in 1983. During the last 14 years, he has worked in diverse fields, such as orbit analysis, position determination systems for search and rescue, LAN-based real-time telemetry data processing systems, and range safety real-time systems. He is currently working as Scientist SE at SHAR. He has published a number of reports and papers in various journals.