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# ADVANCED TELEMETRY SYSTEMS FOR PA TECH. NEEDS, OBJECTIVES & ISSUES

## ADVANCED TELEMETRY SYSTEMS FOR PAYLOADS
## TECHNOLOGY NEEDS, OBJECTIVES & ISSUES: A WHITE PAPER

### Introduction

Payloads refer to systems and users in space. They are usually launched or carried by a space transportation system but are not in any way a functional part of the transportation system. Unmanned spacecrafts, specifically come under this category.

There are two kinds of payloads, those which remain "attached" to the transportation system and those which are separated and become "detached". Detached payloads are transported to geosynchronous or other Earth orbits, placed on deep space trajectories or simply operate (free flyers) in co-orbit. The attached payloads are usually serviced via hardwire links while detached payloads use RF channels. Attached payloads communicate to ground terminals generally via the space transportation system(STS). The STS provides for transmission of data from these payloads, by providing standard or non-standard on board equipment. Standard accomodations usually meets all the user standard data requirements, and provides maximum flexibility and reliability, minimum cost and minimum concern for the services. A non-standard accomodation deviaties from the standard equipment requiring special equipment for a specific payload.

In terms of services to users, functional links to payloads consist of command and low rate telemetry for the forward link, and high rate telemetry (and/or video) for the return link. The return link, usually a high data rate continuous information transmission, requires special processing at suitable nodes of the network path (from the source in the payload to the sink on the ground).

Currently the NASA Space Transportation System supports standard and non-standard users both in 'attached' and 'detached' payload configurations. Onboard avionics supporting the standard user in

each category provides onboard processing of the telemetry data while the non-standard users either process the data to comply with standard interface requirements, or non-standard data is routed by the STS unprocessed in a 'bentpipe' mode.

With the growth in the number of users (spacecraft payloads) and the deployment of new facilities in space, the existing scenario for payload telemetry systems will be impacted. Higher data rates will need to be telemetered on the ground in some flexible format. In many cases a near real-time data reception will be required. How can advanced avionics technologies solve the real space transportation problems of payload telemetry? Namely, support the higher data rates, provide a near real-time data on the ground, and reduce the cost of payload accomodation.

Advanced payload telemetry system development should be focused in the following areas; bulk data transmission, distributed processing, use of networking methods and application of intelligent systems technology. Higher reliability and efficiency are additional concerns for advanced technologies. The development of these technologies are interdependent; for example, bulk data transmission will utilize applications of distributed processing, artificial intelligence technology, and networking methods to achieve higher throughput and efficiency.

## Technology Needs, Objectives and Issues

Advanced technologies currently identified for support of the STS payload telemetry system include the following;
1. Integrated data systems
2. Intelligent system approach
3. Advanced signal processing
4. Payload interface technology
5. Data distribution processing
6. Information compression
7. Voice and data encryption

8. Mass data storage and retrieval
and
9. Advanced modulation and coding.

The current trend in the development of advanced technologies is to integrate all types of data (voice, text, data, graphics and video) such that the signals appear 'alike' to the transmission channel. Such an approach provides commonality of processing, particularly at the intermediate transmission nodes. It also provides transparent communication as far as the end-to-end channel is concerned.

Recent developments in the practical artificial intelligence(AI) hardware/software such as expert systems and artificial neural networks show great promise for advanced telemetry applications. AI concepts for data compression/selection are already being implemented in new designs. Raw sensor data is subjected to 'intelligent conditioning' to help reduce the data volume and to monitor key trends in data changes. Knowledge enhancement/ adaptive sensor techniques are being successfully applied in telemetry systems. Natural user interfaces are similarly upgraded on these lines. The AI concepts are generally implemented as a part of 'embedded' software/hardware architecture. Fault diagnosis applications have become very common. Neural net applications in text/graphic and video are gaining grounds. Reliability of such systems for unsupervised operation is not well established but the systems currently show a great potential in supervised or operator-intensive operation. In cases where intensive decision-making is involved, speed of operation is questionable for real-time operations. A real-time integration issue to be addressed in an intelligent systems approach is an intervention by the operator in a situation where a human life is in danger.

Advanced signal processing refers to implementing standard as well as new innovative algorithms in higher speed technologies to cope with higher mass of data. Both the data compression and data

integration techniques are involved. Data compression is used to remove the redundancy in the source information and save for transmission only the information that is unknown. Data integration refers to the need to 'translate' various kinds of source data-- voice, computer data, video, graphics, etc --into a common data type that will respond to the rigors of channel transmission. The key issue in the signal processing implementation, building a standard architecture for the high-speed digital signal processor, has been solved. Several 'common' signal processors based on variations of common architectures for DOD standard avionics high-speed signal processors (parallel pipeline processing architecture) have been designed by vendors such as IBM, Hughes, AT&T, and Northrup. These are characterized by modular design, standard interconnection backplane, test/maintenance bus, data transfer network, etc. They provide processing of feature extractions, images and signatures, and have global memory elements. The state-of-the-art, i.e., vector quantization for images, LPC for voice, etc., appear adequate for the need as most of the hardware is available to implement real-time operation in a space-qualified environment. AI technology of neural networks is being applied to the data analysis tasks successfully.

Payload interface technology is yet another area which is being developed. The effort is to design a standard interface such that the system is easily reconfigurable. Interface parameters include data and clock rates and mode of transfer at the physical interfaces. Protocols for data transfers and provisions for standard user interfaces for log-on, dial-up, or menu/selection tree (user-friendly), have been developed. AI techniques will find good applications in interface reconfiguration.

The payload telemetry system should be capable of routine extraction/ formatting/manipulation of user data and user data monitoring, for example, histogrammming, plotting, spectral transforms, etc. These services, if offered, may involve special data protocols, data rates, and link services (full duplex, half duplex, etc). An economic as well as technical issue will be involved in the

partitioning between onboard, and distributed processing. The level of processing by the user, on the ground and onboard at different transmission nodes will provide a variety of burdens for both the user and the space transportation system. For efficient distribution, advanced higher speed multiplexers and statistical concentrator algorithms will be employed. Network technology to move the data around efficiently will be used. The use of fiber optics for internal networking and distribution is well recognized.

In order to have an effective handle on the data flow from/to the payload, the size of the payload data traffic should be reduced by an efficient lossless compression. Straight forward data compression of channel bit rate will be clearly desirable, but there will probably also be a clear trend for analyzed data only, with temporary backup storage and transmission of stored data. This information compression processing involves new approaches to noiseless coding (LPC/vector quantization extension) and provision for signal transformation, statistical analysis, and efficient presentation formats.

The space transportation system environment will be used by a variety of common authorized users with at least indirect access to the total transmission media. Therefore some degree of privacy (e.g. encryption of virtual channels) will be required wherein users will be able to utilize only the data specifically addressed to them, even though they may be able to access the entire multiplexed data stream contained on the transmission media. The virtual channel between the payload and the ground, which is independent of actual routing path, will facilitate privacy. In theory, the technology to assure privacy is available today. The data encryption standard (DES) for commercial activities is sufficient for protection against all except concerted attack. However, three issues need consideration. The first issue is speed of operation. Operation of encryption technology at very high data rates is yet to be developed. The second issue is the key distribution problem similar to computer access passwords today. Standards provide ways of implementing/managing keys with

varying levels of privacy assurances, but implementing a uniform system-wide management strategy will be difficult. In a large multiport, multimode environment, the assurance mechanism that keeps keys up-to-date and properly distributed will not be a simple task. A possible AI application may be inevitable. The third issue is the interaction of the encryption mechanism with the channel error coding and addressing (routing) protocols. The transmission medium must have either unencrypted or commonly encrypted routing information to properly forward data via the designated virtual channel. Further, the encryption mechanism is useless if it cannot cope with the reality that the channel will itself provide corrupted data to the end user.

With the growth of the payload data, mass data storage and retrieval will become very important. The data will probably be stored on optical disks with very high read/write rates and will have up to tera-byte capacity. With such a large quantity, a provision for fast retrieval of data will be needed. An intelligent data base that can provide resource management, allocate services to competing users and interface with the ground user to set up comunications, will become part of the system.

The objective of advanced modulation and coding is to provide improved system performance in terms of increased bandwidth and power efficiency while minimizing transmission errors and the effects of interference. New techniques that combine both the modulation and coding are being developed. Quadrature amplitude modulation (QAM) is a digital modulation scheme designed for a ground based microwave telephone link to provide premium bandwidth conservation. Trellis modulation (TCM), by virtue of adding the error-correction code as part of the modulation, is a prime candidate for high data rate transmission. Other schemes based on spectrum, spreading such as CDMA and FH provide interference immunity. They are also characterized by slowly degrading performance as the signal to noise ratio is reduced. It is also likely that synchronization will be an issue for the advanced modulation

scheme. Parallel processing architectures are being evolved to handle the high data rates.

## Conclusion

The current trends in advanced payload telemetry are the new developments in advanced modulation/coding, the applications of 'intelligent' techniques, data distribution processing, and advanced signal processing methodologies. Concerted efforts will be required to design ultra reliable man-rated software to cope with these applications. The 'intelligence' embedded and distributed throughout various segments of the telemetry system will need to be overridden by an operator in case of life-threatening situations, making it a real-time integration issue. Suitable MIL standards on physical interfaces and protocols will be adopted to suit the payload telemetry system. New technologies and techniques will be developed for fast retrieval of mass data.

Currently, these technology issues are being addressed to provide more efficient, reliable, and reconfigurable systems. There is a need, however, to change the operation culture. The current role of NASA as a leader in developing all the new innovative hardware should be altered to save both time and money. We should use all the available hardware/ software developed by the industry  and use the existing standards such as FDDI, ISO/OSI, STDN, rather than inventing our own.

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