UNIQUE SYSTEMS THROUGH REUSABLE SOFTWARE

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ABSTRACT

Computer Sciences Corporation, Realtime Data Systems Center has developed, integrated, tested, and delivered several large telemetry systems to various ranges over the past eight years. One key to the success of these systems has been the ability to build on a software base to meet unique range processing requirements for aircraft, missiles, and related weapons systems. Reusable software means reduced procurement and life cycle costs. The ability to successfully reuse software for new systems with new requirements lies not only in the fundamentals of modular system design, but in the ability of the people to comprehend the design, and adapt the software to new requirements. As advanced telemetry processing needs meet reduced budgets, the successful systems integrator will be relying more and more on an ability to adapt existing systems to meet new challenges.

Key Words: Telemetry Systems
Reusable Software
Reusable Design

INTRODUCTION

As an organization, the Realtime Data Systems Center (RDSC) for Computer Sciences Corporation (CSC) first entered the telemetry systems integration business in September 1981. At that time the Air Force Flight Test Center (AFFTC) awarded CSC a contract to develop the Integrated Flight Data Processing System (IFDAPS) for the Ridley Mission Control Center (RMCC). The assembled team drew from a wide experience base. Expertise from such systems as the then newly developed Telemetry Integrated Processing System (TIPS) installed by Systems Development Corporation at Vandenberg Air Force Base, and operational experience from various telemetry, radar, and satellite control facilities provided the experience base needed to develop and deliver the RMCC system and several other telemetry systems over the past eight years.

The ability to apply past experience towards the new system was significant for RMCC, but the ability to adapt and reuse the software developed for RMCC on other related telemetry systems (1) was crucial. Reapplication of key software modules and major design concepts enabled these systems to meet performance criteria, as well as stay within schedule and cost constraints.

The reusability of software has begun to receive a great deal of attention in various government agencies. As an example, the National Test Bed for the Strategic Defense Initiative is holding Symposia to define how to best make use of similar software across program and contractor boundaries (2). Reusability of software is a natural concern where budgetary issues impose limits on development.

Newly developed software is inherently more expensive than rehosted software, especially if the software design must also be built from scratch. Existing software represents an invaluable knowledge base. The reuse of software includes the reuse of software modules across projects, but of greater consequence is the reuse and adaptation of software design (3) yielding modified or new code to meet new requirements. It is the latter ability that has enabled CSC RDSC to deliver systems within relatively short schedules (4).

This paper presents the interrelationships of several telemetry processing systems, and shows how the reuse of software and software designs affects costs.

RDSC Telemetry Systems Architecture

The telemetry processing systems developed by RDSC share common design attributes (Figure 1). Setup software is provided for pre-test definition of the telemetry processing scenario. Setup files are built by a telemetry compiler to be loaded into telemetry preprocessor front end equipment. This preprocessor is programmed to acquire the telemetry data, perform the majority of data processing, and distribute the processed data to the host computer(s) for presentation to the users or further analysis. Acquisition of PCM, FM, and other telemetry data by the preprocessor entails the normal synchronization, syllablization, and ID tagging. Processing in the preprocessor includes Engineering Unit conversion, Data Compression, and Data Type conversion to a format acceptable to the host processor(s). The preprocessor's final function is to make data available to the host processors via direct memory data transfer.

With the data now in the host, in a format ready for use, the host processor(s) functions include realtime presentation of the data on high resolution display formats, digital history recording of the telemetry data, realtime analysis, and intermaneuver or post-test analysis of the history recorded data (5, 6). All of the realtime processing capabilities require realtime control. Modification of the processing sequence and characteristics are provided

for the flight test engineer to modify the test environment, ensure data quality, and maximize the results for any given test (7).

The final common element to RDSC telemetry systems is the networking capacity necessary to tie multiple computers into one common telemetry test stream, or tie multiple test streams together into one integrated system. Various combinations of shared memory and high speed interprocessor communications have been installed to meet different interprocessor communications requirements. It is no longer sufficient for telemetry ground stations to acquire and store data for later data reduction and analysis (8). The capacity to network realtime data to various engineering analysis stations enables the realtime analyst (9) to make maximum use of flight test time.

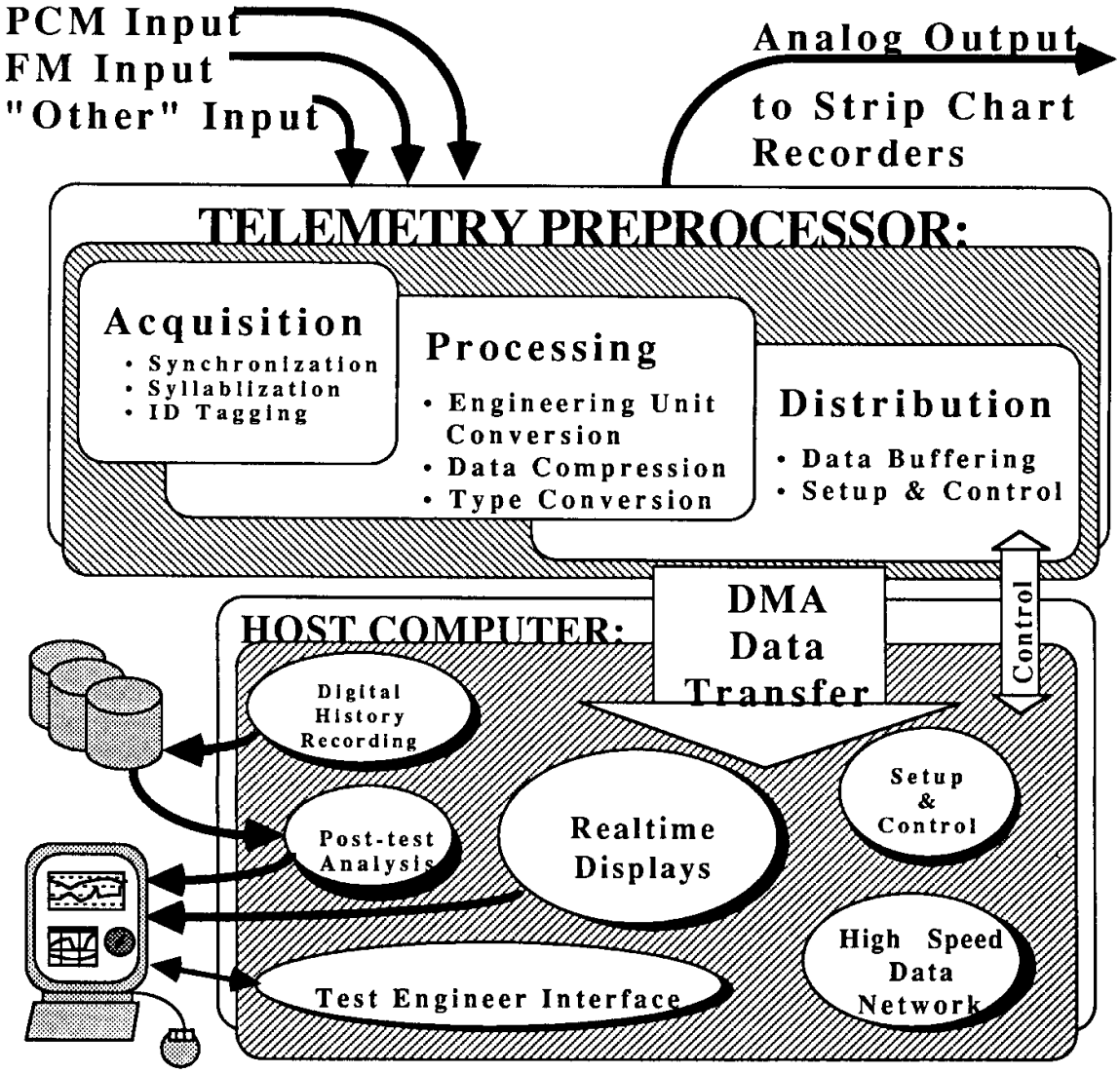

Figure 1. Telemetry Processing System Architecture

Genealogy of RDSC Telemetry Systems

The telemetry processing systems delivered by RDSC share a common background for system design and software (Figure 2). The software development effort for each project and the software technical knowledge transfer between projects is represented as a function of time. Each of these systems represents an application of the common system design approach to meet specific requirements.

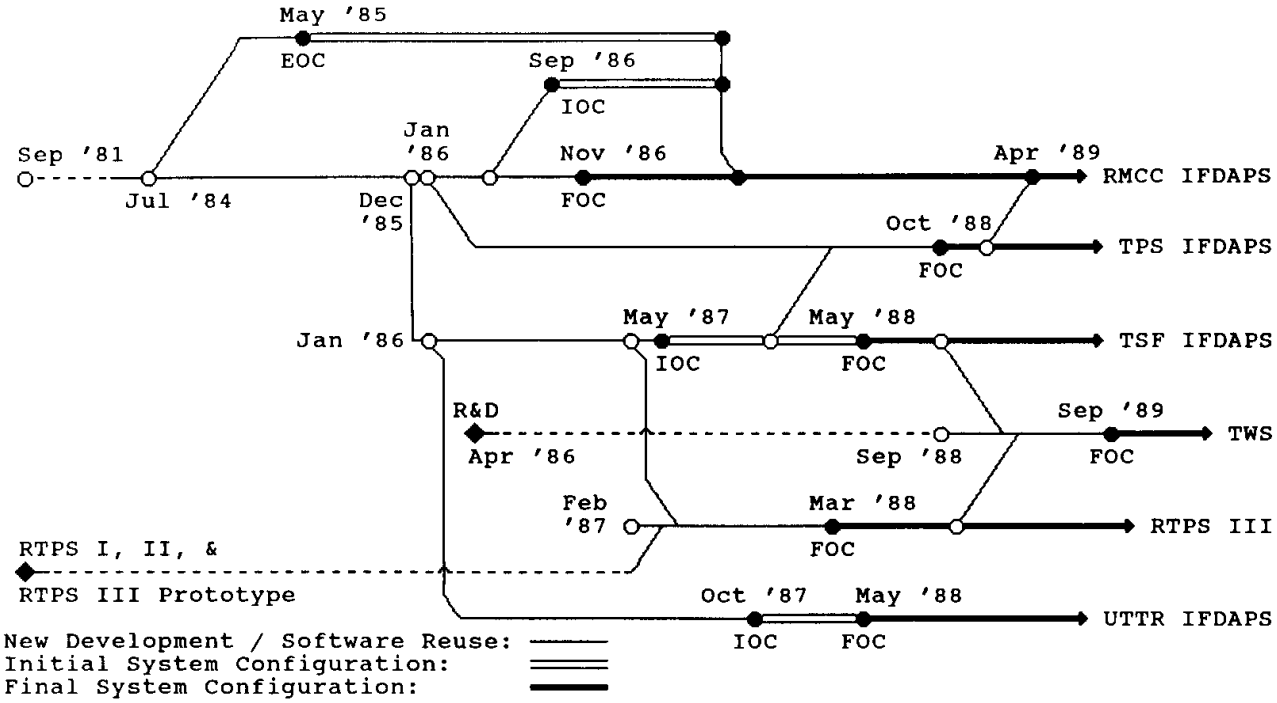

Figure 2. RDSC Telemetry Systems Genealogy

Ridley Mission Control Center IFDAPS

The RMCC system (10, 11, 12) forms the cornerstone for the telemetry processing systems developed by RDSC. Beginning in September 1981, CSC engineered the system to satisfy AFFTC requirements.

In the summer of 1984, the Air Force identified a need for an Early Operational Configuration (EOC) which was delivered in May of 1985. A second system was delivered as the Initial Operational Configuration (IOC) in September 1986. Both the EOC and IOC systems represent RMCC software tailored for hardware configurations and operational considerations different from the final baseline configuration. The software differences were small, but these systems are significant in that they represent the first RDSC systems to benefit from the reuse of software design.

The final three baseline systems were delivered in the Final Operational Configuration (FOC) in November 1986. The EOC and IOC systems were later integrated with the baseline systems, and RMCC IFDAPS has been supporting AFFTC flight test operations since that time. The RMCC system required approximately 576 man-months (MM) to develop 332,000 lines of executable, Deliverable Source Instructions (DSI) over five years.

A relative cost of software development by project, as measured by MM / DSI (Figure 3) indicates the substantial drop in development costs for the systems which grew from the RMCC software investment. The subsequent projects, while incorporating more features and meeting higher technical demands, show a reduced software development cost. This is due to their dependance on the reuse of software from the original and succeeding systems (3).

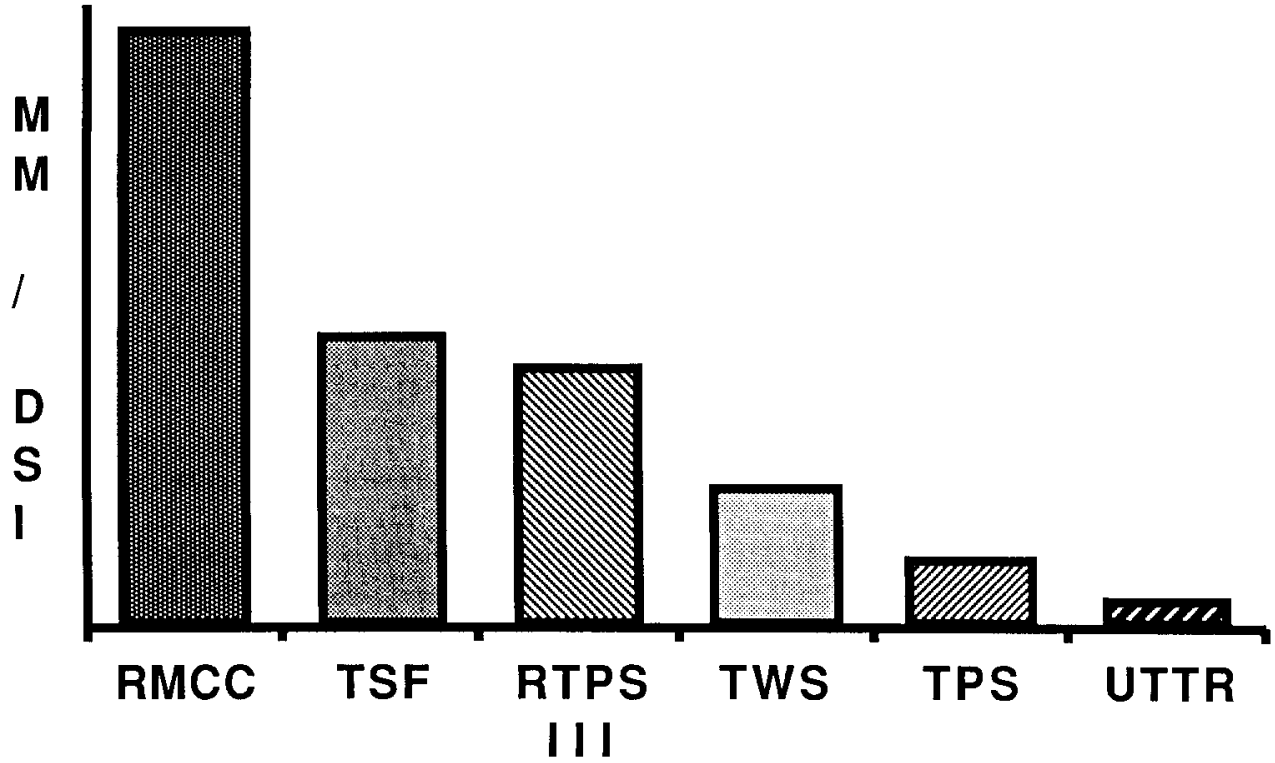

Figure 3. Cost of Software Development by Project

Test Support Facility IFDAPS

In December 1985, AFFTC awarded CSC RDSC a contract to provide the Test Support Facility (TSF) (5). This set of three systems relied heavily on software developed for RMCC. The Government's demanding requirements were met through the application of the existing software. Modifications of the existing software enabled the use of more advanced technologies across the entire system. Newer front end preprocessors were

integrated. Higher performance recording and displays were incorporated. Array processing capabilities were integrated across the pre-test, realtime, and post-test analysis software. For the TSF system, a system with many enhanced capabilities, 560,000 DSI were delivered using 480 MM in under 3 years. By building the more advanced system on the RMCC baseline, the TSF development time was significantly reduced, and the cost of software (Figure 3) was reduced to half of what the system would have cost.

Test Pilot School IFDAPS

Both RMCC and TSF have smaller derivative systems designed to meet specific user needs (1). Test Pilot School (TPS) IFDAPS was procured by the USAF Test Pilot School at Edwards Air Force Base (AFB) to support their training mission. The TPS software effort represents a moderate rehost of RMCC software, along with some of the TSF software, to accommodate single processor configurations. Minor front end processor and other hardware configuration differences were also incorporated. Over 145,000 DSI were rehosted to generate the TPS system, taking 24 MM in less than one year of development time. The significant amount of reusable software incorporated into TPS dropped the software costs (Figure 3) to $1/8^{th}$ of that expected for new development. The inclusion of code from TSF enabled TPS to use newer host processors.

The TPS effort provided an additional benefit for RMCC, the original system. During the spring of ’89, the RMCC acquisition processors and software were similarly upgraded to the newer host processors yielding increased system throughput and performance. The investment in reusable design and software thus provided a dividend in the full life cycle costs for RMCC.

Utah Test and Training Range IFDAPS

The Utah Test and Training Range (UTTR) system was built on the TSF system design, This effort represents the smallest cost for software development (Figure 3). Over 450,000 DSI were rehosted in 40 MM and in less than one year. UTTR represents the rehost effort with the smallest impact to system design, and therefore the greatest reuse of unchanged software. A minimal number of source modules (less than 10%) were modified to accommodate the differences in configuration. The UTTR and TSF resultant systems share a tightly coupled software set. Each site benefits from enhancements and corrections identified by the other.

Real-time Telemetry Processing System III

The RDSC telemetry processing system which made the most use of existing software was Real-time Telemetry Processing System III (RTPS III) developed for the Patuxent River

Naval Air Test Center (13). The RTPS III project (4), a firm fixed price contract, relied heavily on the reusable design and the capability to merge software from three sources. First, the RTPS prototype software developed by the Government (14) provided most of the user interface and display software. By Government direction, this software also retained much of the user interface style of the original RTPS I and II systems. The retention of the user interface was important to preserve the knowledge investment of the RTPS users. Second, TSF software was modified to generate the new setup file software, and front end processing software necessary to load and control the front end equipment. Third, newly developed software provided new functionality over the previous systems.

Three key components came together to make the RTPS III project a success (4):

- A technically astute customer made an investment in prototyping the required capabilities and made the prototype software available for reuse.

- A talented core of senior team leaders made maximum use of the existing TSF system design and software.

- The implementation of Computer Aided Software Engineering (CASE) for system design provided for rapid transition of design knowledge.

These factors enabled the development and delivery of the 170,000 DSI which comprised the RTPS III system, with the expenditure of only 130 MM, and 13 months total end-to-end development time. As indicated by Figure 3, by relying on the previously developed software, RTPS III was developed at half the costs of new development.

Telemetry WorkStation

The Telemetry WorkStation project (TWS) represents the most recent application of existing RDSC telemetry software (1). The TWS project was created to allow for a choice of host processors. It took full advantage of the software investment represented by the previous systems. The rehost of 140,000 DSI for the initial TWS capability represents an expenditure of 58 MM spread over several years. The initial display capability was demonstrated at the 1986 International Telemetering Conference. TWS represents the next step in the telemetry systems architecture, by incorporating network and workstation capabilities. While still relying on the telemetry preprocessor to acquire, process, and distribute data to the host processor, the system has been engineered to make maximum use of distributed processing.

The integrated network has also been retained in the TWS design in two forms. Multiple engineer systems are configured using high speed interprocessor communications network,

direct access shared memory capability. The application of reusable software provides the capability for multi-disciplined display stations and fully redundant data acquisition stations within the same network. Each station in the network has full access to all the data, and can make locally processed information available to any of the engineers through the entire system.

CONCLUSION

Future systems will continue to be built on the knowledge base represented by the current systems. If for no other reason, projected Government funding, in conjunction with competitive fixed price procurement practices, will direct the systems integration industry to take full advantage of the existing software base. The reuse of software, in the form of unchanged, reusable modules plays an important role, but represents the prosaic, common sense distribution of existing software capabilities through software libraries. The greater potential for success is represented by the ability to apply existing system designs in conjunction with the growing library base, towards the creation of system designs satisfying the new requirements.

The ability to design a system to meet new requirements is the ability to successfully decompose the new requirements. Decomposition is the technique of breaking down of a new set of system requirements into elements: functions, units, smaller pieces. Decomposition becomes the method to transition from the abstract “unimplementable” to the “implementable”. With an extensive systems background, and specialization in specific systems, the point at which this recognition occurs is much sooner in the system design process. As system integrators deliver multiple unique systems, in addition to the accumulation of system expertise, the libraries of software from which to draw also grows.

The telemetry processing systems delivered by RDSC represent the successful application of the reuse of system design and software. This was made possible through the investment in the system design at the inception of each project, and the continuity of the senior technical staff disseminating their knowledge across projects.

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REFERENCES

1. Shelley, Larry, and McCauley, Bob, "Accommodating Telemetry Data Acquisition Systems", International Telemetering Conference, Vol. XXIII, Instrument Society of America, Research Triangle Park, North Carolina, October 1987, pp 51-60.

2. Morrison, Lt. Col. J, and McCauley, R. "Reuse and the Software Revolution Symposium", Proceedings, Falcon Air Force Base, Colorado Springs, Colorado, February 1989.

3. Freeman, P, Software Perspectives The System is the Message, Addison-Wesley Publishing Company, Reading, MA, 1987.

4. Hill, Jerry L., "Real-time Telemetry Processing System (RTPS) III: A Preview of Software Development in the 1990s", International Telemetering Conference, Vol. XXIV, Instrument Society of America, Research Triangle Park, North Carolina, October 1988, pp 257-266.

5. Quesenberry, Dave, and Reed, Gary, "Telemetry Processing - Realtime to Postflight", International Telemetering Conference, Vol. XXIV, Instrument Society of America, Research Triangle Park, North Carolina, October 1988, pp 237-246.

6. Erwin, Dennis, and Dobbs, Randy, "IFDAPS Postflight Capabilities", AIAA-86-9768, AIAA/AHS/IES/SETP/SFTE/DGLR 3rd Flight Testing Conference, Las Vegas, Nevada, October 1986.

7. Shelley, Larry, "Best Seat in the House", Society of Flight Test Engineers, 15th Annual Symposium Proceedings, St. Louis, Missouri, August 1984.

8. Davino, R., and Flattery, D., "Integrated Flight Data Processing System: Support for the Discipline Engineer", AIAA-85-4042, AIAA/AHS/ASEE Aircraft Design Systems and Operations Meeting, Colorado Springs, Colorado, October 1985.

9. McCauley, Bob, "Expert Systems in Data Acquisition", International Telemetering Conference, Vol. XXIII, Instrument Society of America, Research Triangle Park, North Carolina, October 1987, pp 41-49.

10. Fanus, Dick, "IFDAPS: A Hardware Overview", Society of Flight Test Engineers, 15th Annual Symposium Proceedings, St. Louis, Missouri, August 1984.

11. McCauley, Bob, “IFDAPS: A Software Overview”, Society of Flight Test Engineers, 15th Annual Symposium Proceedings, St. Louis, Missouri, August 1984.

12. Idsardi, Robert H., “A Distributed, Real Time, Flight Test System”, AIAA-83-2732, AIAA/AHS/IES/SETP/SFTE/DGLR 2nd Flight Testing Conference, Las Vegas, Nevada, November 1983.

13. Shelley, Larry R., “The Real-Time Telemetry Processing System III”, International Telemetering Conference, Vol. XXIII, Instrument Society of America, Research Triangle Park, North Carolina, October 1987, pp 329-336.

14. Hummel, W., “Telemetry System Prototype Development”, Society of Flight Test Engineers, 15th Annual Symposium Proceedings, St. Louis, Missouri, August 1984.

NOMENCLATURE

AFB	Air Force Base
AFFTC	Air Force Flight Test Center
CASE	Computer Aided Software Engineering
CSC	Computer Sciences Corporation
DSI	Deliverable Source Instructions
EOC	Early Operational Configuration
FOC	Final Operational Configuration
IFDAPS	Integrated Flight Data Processing System
IOC	Initial Operational Configuration
MM	Man-Months
RDSC	Realtime Data Systems Center
RMCC	Ridley Mission Control Center
RTPS	Real-time Telemetry Processing System
TIPS	Telemetry Integrated Processing System
TPS	Test Pilot School
TSF	Test Support Facility
TWS	Telemetry WorkStation
UTTR	Utah Test and Training Range