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B-2 AND OTHER CURRENT FLIGHT TEST CONTROL CENTER SYSTEM ARCHITECTURES

CZ790293

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OVERVIEW

CLIENT	***SYSTEMS***	***OBJECTIVE***
USAF-EAFB	**B-2 Test Support Facility (TSF)**	**B-2 Flight Testing**
USN-PMTC	**Telemetry Processing System (TPS)**	**Weapon (Missile) Testing**
USN-NATC	**Real-Time Telemetry Processing System (RTPS III)**	**Aircraft Flight Testing**

CSC

KEY POINTS / THEME

- TELEMETRY PROCESSING INDEPENDENT OF SOURCE
- GENERIC SYSTEM / SOFTWARE
- TIME HOMOGENEITY
- LOW LATENCY NETWORKS
- DISTRIBUTED PROCESSING
- ALL DATA AVAILABLE TO ALL WORKSTATIONS
- RECALL OF DATA IN REALTIME
- NO FREEZE H/C
- TEAM CONCEPT
  - CSC Continuity
  - Client Involvement

TEST SUPPORT FACILITY
MISSION CONTROL ROOM

The Test Support Facility (TSF) is comprised of three (soon to be four) control rooms. Each control room contains:

1. Two Large Screen Displays.
2. Ten high resolution, rasterized, color displays with up to 1000 user-defined displays.
3. Three alphanumeric terminals.
4. 128 stripchart pens.

The TSF provides the following processing capabilities:

1. Process two, 1.2 Mb/Sec telemetry sources.
2. Engineering Unit (EU) conversion of 156K samples per second.
3. FM processing of 72 channels with aggregate rate of 300 K samples per second.
4. Maximimum number of measurements defineable is 10,000.
5. Record 300K samples per second with aggregate on-line archival of up to 3 Terabytes for 3 control rooms (one year's data).

Test Support Facility PERFORMANCE SUMMARY

- **SUPPORT 3 SIMULTANEOUS MISSIONS**

- **SINGLE MISSION REQUIREMENTS**
  - Three 1.2 Mbit PCM
  - One FM (72 Channels)
  - 10,000 Measurements / 300,00 sps / 156,000 EUC

- **FACILITY REQUIREMENTS**
  - One Year of Mission Data On-Line (3 Terabytes)
  - Two Minute Retrieval of Any Mission
  - Two Floors: 1 Computer Room (10,000 sq. ft.)
3 Mission Control Rooms (5,600 sq. ft.)

TSF CONFIGURATION

The TSF architecture is made up of the following subsystems and components.

Flight Monitoring System (FMS) - Each of three FMSs supports a Mission Control Room. An FMS consists of three mini-computers providing a combined processing capacity of approximately 20 MIPS. There is one processor assigned to each of three functions: Acquisition, History Recording and Display. A telemetry front end provides bit and frame synchronization, decommutation and EU conversion prior to receipt by the mini-computers. Additionally, the front end drives 128 stripchart recorders.

1. Acquisition ingests telemetry data from 72 FM channels with and agregate rate of 300Ksps and from two 1.2Mb PCM streams. Processing provides EU conversion, time tagging for time-homogeneous data and stripchart recording. Fast Fourier Transforms and other compute-intensive processing are supported by an array processor coupled to the acquisition processor. All bit sync, frame sync and decommutation are performed in the special purpose telemetry front end.

2. Realtime display provides display processing for 10 color graphics terminals, three alphanumeric terminals and two large screen displays.

3. History recording is performed for all telemetry data received. This includes 300Ksps raw or 156Ksps EU converted data. Recorded data may be "recalled" from the history recording subsystem in realtime.

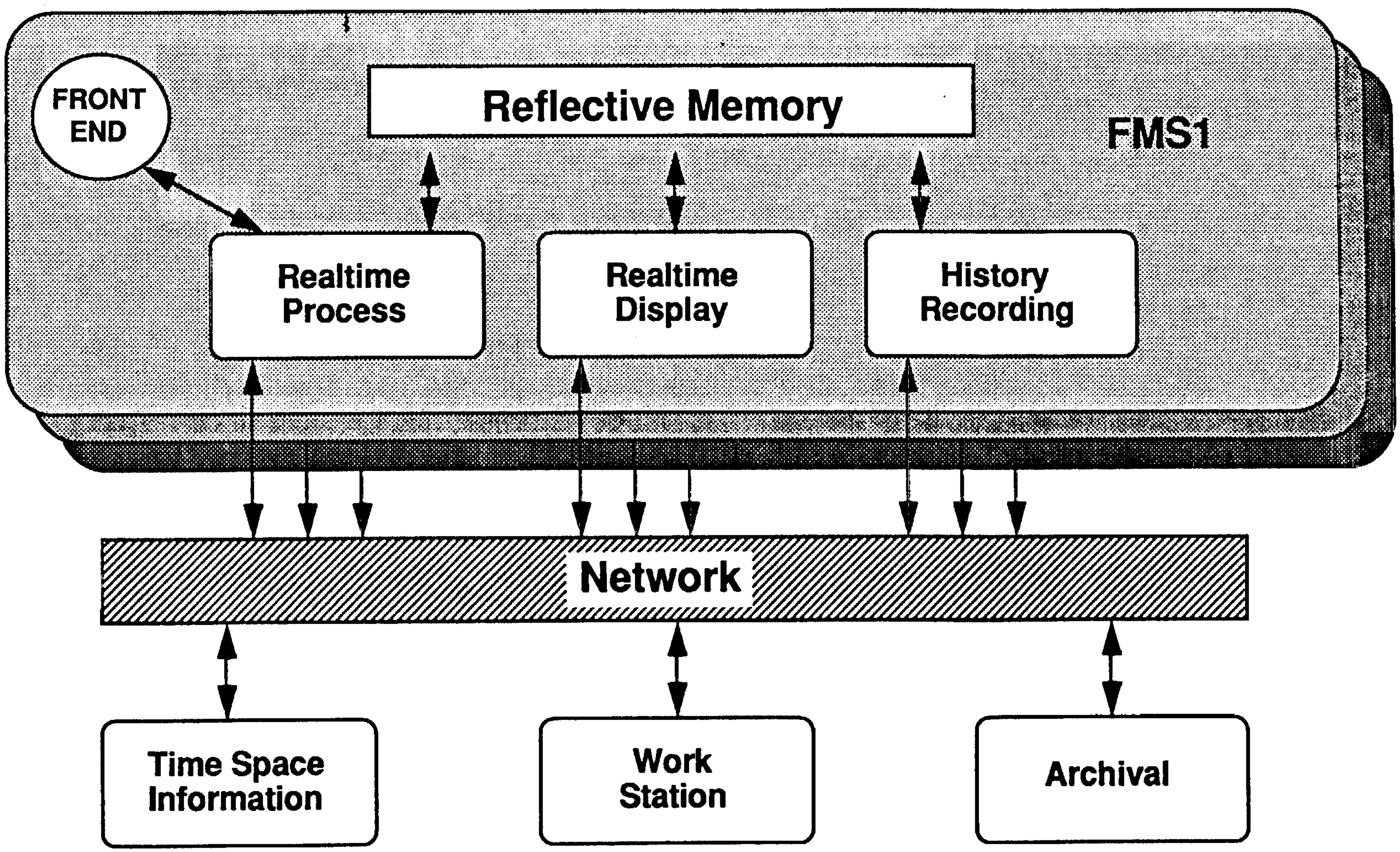
Flight Monitoring System (FMS) Common Functions - Several functions are shared by all control rooms via a high speed network communications link. These functions are described below:

An on-line, mass storage, archival system is available to all control rooms. This Storage Archival System (SAS) provides three trillion bytes (3 terabytes) of archived storage from which files of up to 123MB can be accessed within 90 seconds.

A pool of Engineering Workstations (FMSs) is available to all control rooms. The primary function of these workstations is to provide telemetry processing and display definitions for the three Flight Monitoring Systems.

Time Space Position Information (TSPI) is provided for all FMSs from the TSPI processors over the network communications link. This information is used to direct intercepts, bomb drops and other operations requiring exact vehicle position and track prediction information.

TSF ARCHITECTURE



B-2 EVOLUTION

A fourth Flight Monitoring System (FMS) is being added to the existing three FMSs in the TSF. This upgrade will be functionally transparent to the operation and consist of the following replacements:

1. Two of the three FMS mini computers replaced with a single, more powerful mini.

2. Ten graphics terminals replaced with workstations.

3. Three terabyte Storage Archival System replaced with a 6 terabyte system.

Intelligence for processing operator commands from the current graphics terminals resides in the minis. This processing will be performed in the workstation with the workstation retaining all graphics display functionality previously exhibited by the existing display stations. This will be done while not modifying existing software. The goal is to only add more hardware and software, providing for a single system from a maintenance perspective.

A Yourdon analysis was performed using a CASE tool to insure all interfaces were thoroughly understood and documented before the upgrade was attempted.

Test Support Facility
EVOLUTION

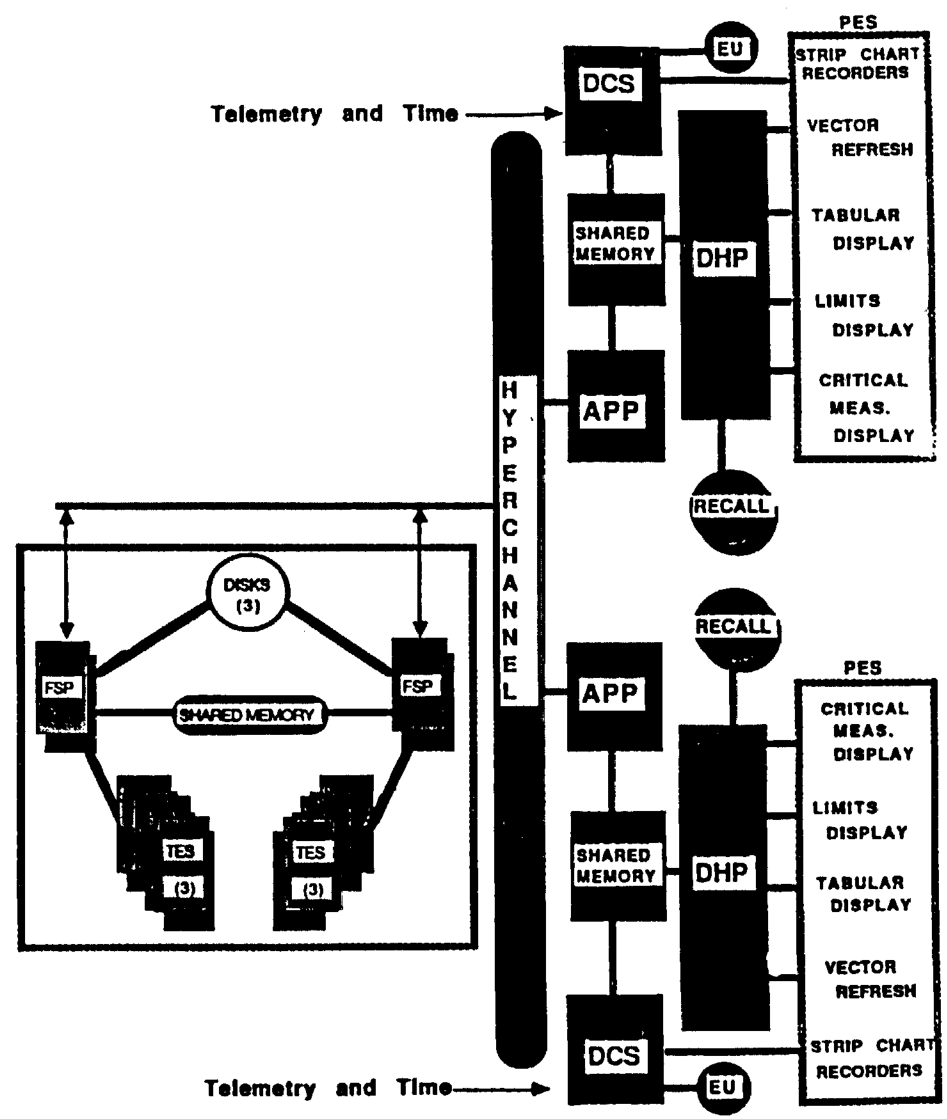
- REPLACE DISPLAY HOST WITH A WORKSTATION BASED OPEN SOLUTION
- USE THE UMN TO ENABLE SEAMLESS ARCHITECTURE
- PROVIDE LIFE CYCLE UPDATES OF PROCESSOR/DISKS
- DOUBLE THE CAPACITY/DENSITY OF VERY LARGE ARCHIVE

RTPS III CAPABILITIES

The Realtime Processing System (third generation) upgrades the current flight test capability to state-of-the-art systems. RTPS III consists a Control Center, made up of six control rooms, and is expandable to at least eight. Each Control Center has the following capabilities:

1. Process as many as four 10Mb PCM sources.
2. Process as many as 64 FM channels with an aggregate throughput of 200Ksps.
3. Perform EU conversion at 200Ksps.
4. Record EU data in frame format and order at 160Ksps.
5. Define 2K telemetry measurements.
6. Time homogeneous CVT and recording buffers.
7. Recall of recorded data for display during realtime.
8. No-freeze hardcopy of graphics and alphanumeric displays.

RTPS III BLOCK DIAGRAM



CONTROL CENTER ARCHITECTURE

Each of six control rooms consists of a triad of mini-computers with a connecting shared memory system. Each CPU in the triad represents a subsystem performing a major system function. The six control rooms share a common file management system, accessible over a high-speed network.

Data Channel Subsystem - The Data Channel Subsystem provides for bit sync., frame sync., decommutation and time tagging, EU conversion and recording, limit checking, stripchart recording and data distribution. This subsystem consists of a special purpose front end working in tandem with, and driven by, one of three mini-computers. CVT data are provided to shared memory by the CPU and via DMA from the front end. Note that all bit sync, frame sync and decommutation are performed in the special purpose telemetry front end.

Display Host Processor - The Display Host Processor drives the control center displays from the CVT data provided by the Data Channel Subsystem. These data are also recorded in a circular mass storage file from whence they may be recalled and displayed on either of the two graphics displays during realtime. Control and display devices provided by this subsystem are:

1. Two monochrome graphics (vector refresh) terminals.
2. Two Critical Measurement Displays (12 selectable measurements each LED panel).
3. Two fixed-function keyboards (64, one-keystroke functions).
4. Two limits displays (color).
5. Two tabular displays with graphics capability (color).
6. Two lazer hardcopy devices for vector refresh terminals.
7. Two color hardcopy devices for color graphics terminals.
8. 128 stripchart channels (driven from Data Channel Subsystem processing).

Application Subsystem - The Application Subsystem consists of a 10 MIP mini-computer and associated array processor. This subsystem provides user-defined, compute-intensive processing. Data are provided by the Display Host Porcessor and Data Channel Subsystem through the shared memory interface. Processed data and derived measurements are returned to those two subsystems from the Applications Subsystem through the same interface.

File System Processor - The File System Processor Subsystem provides operation definition for all operations conducted from any control room. Telemetry formats and processing are described by the Telemetry Engineer. Files are generated for distribution, on the high-speed network, to the applicable control room processors for control of all processing and display directives associated with a specific operation.

Cost: The capabilities described above were provided for an average cost of $3.3M control room, including the File System and high-speed network.

TELEMETRY PROCESSING SYSTEM CAPABILITIES

The Telemetry Processing System (TPS) was 22 months in development and is currently undergoing factory acceptance testing in Lompoc, California. Installation at the Pacific Missile Test Center at Pt. Mugu is scheduled for August, 1991. The TPS consists of four processing subsystems (TPSS) that are switchable between four control rooms. TPS capabilities for each control room are as follows:

1. Process up to eight telemetry input sources including:

    a. Four 10Mb PCM links.

    b. FM (20 channels, aggregate of 300Ksps).

    c. Two PAM links.

2. Perform EU conversion at 400Ksps (Mix = 80% Ax + b, 10% 5th Order Polynomial and 10% Table Lookup.

3. Recording of 360Ksps EU converted measurements.

4. Define up to 16K measurements.

5. Playback of digital data from mass storage.

6. Recall of recorded data in realtime.

TPS ARCHITECTURE

The TPS architecture consists of four control rooms supported by four processing subsystems. Processing subsystems are switchable between control rooms. The special purpose telemetry front end is interfaced to the host through a proprietary high-speed data interface. CVT data are provided to all workstations over an Ethernet interface. Data are provided to the Range Central Site Computers over a high-speed (100Mbps) network. Workstations in a control room can receive data from any two processing subsystems simultaneously. Data from any of the processing systems can be provided to all four of the control rooms simultaneously. Stripcharts in the control rooms are driven directly from the special purpose telemetry front end. All bit sync, frame sync and decommutation functions are performed by the special purpose telemetry front end. The specific subsystems are as follows:

<u>Telemetry Front End Subsystem</u> - The TFESS performs bit sync., frame sync., decommutation, ID and time tagging, EU conversion, stripchart processing. Data are provided to the Telemetry Processing Subsystem (TPSS) and Telemetry Display Subsystem (TDSS) over the Intelligent Data Interface (IDI)/Universal Memory Network (UMN) high-speed data network.

<u>Telemetry Processing Subsystem</u> - The TPSS controls the TFESS, and provides processed data to the TDSS workstations. The interface to the TDSS is Ethernet. Data are transmitted to and received from the Range Central Site Computers over the Telemetry Data Network (a 100Mb link). A second Ethernet link provides communication with the Software Development Station and the Telemetry Decommutation and Processing System.

<u>Telemetry Display Subsystem</u> - The TDSS receives data from the TPSS over Ethernet and from the TFESS through the UMN interface. Data are displayed on four 19" color graphics workstation monitors. Every workstation has access to all measurements in given subsets, as defined in a database distributed prior to the operation. Data may be recorded to the local workstation disk and recalled in realtime. A TDSS consists of:

1. Four workstations with 19" color graphics monitor and local mass storage.

2. One color hardcopy device shared by four workstations.

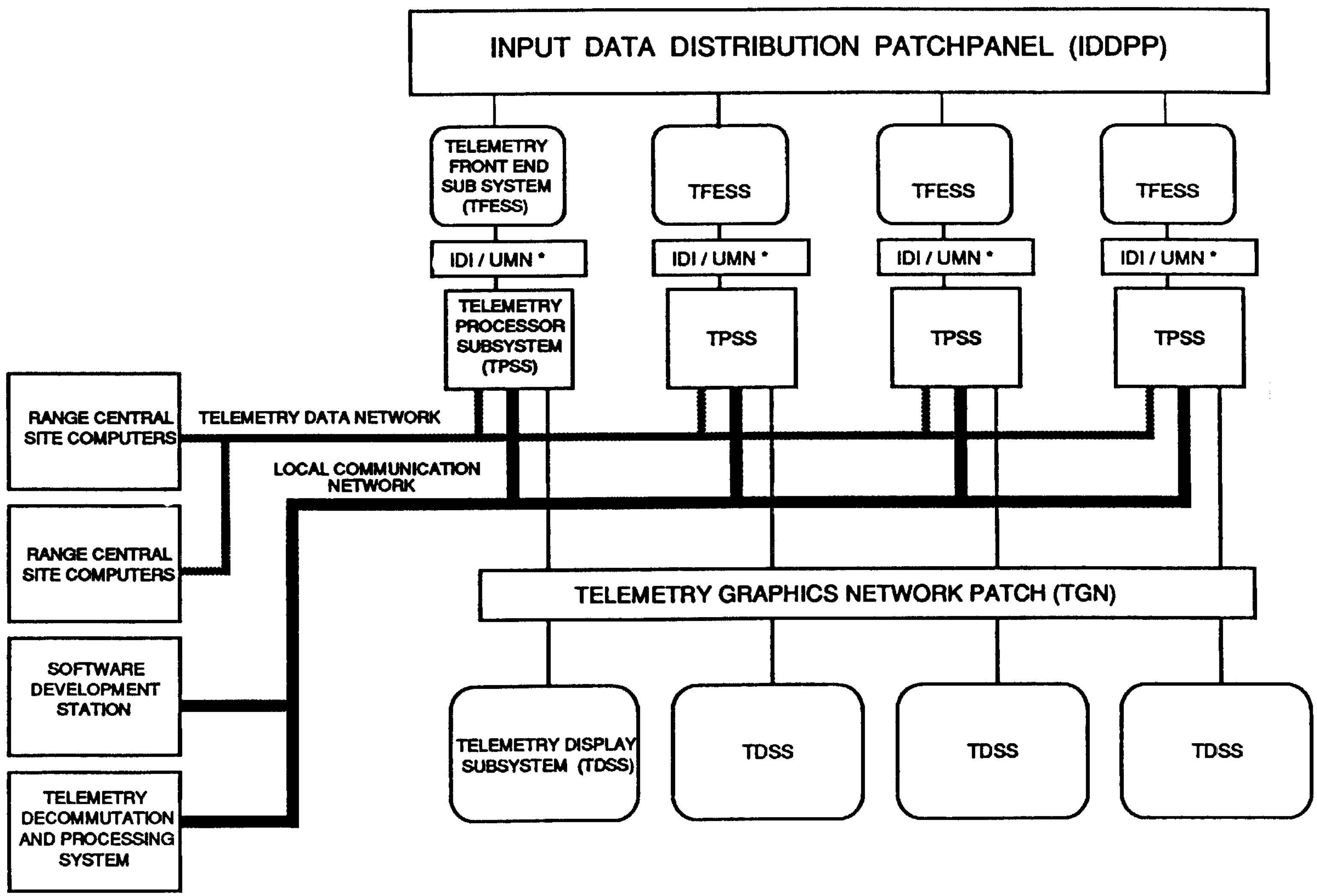
3. Four monochrome hardcopy devices (one per workstation).

4. 64 stripchart pens.

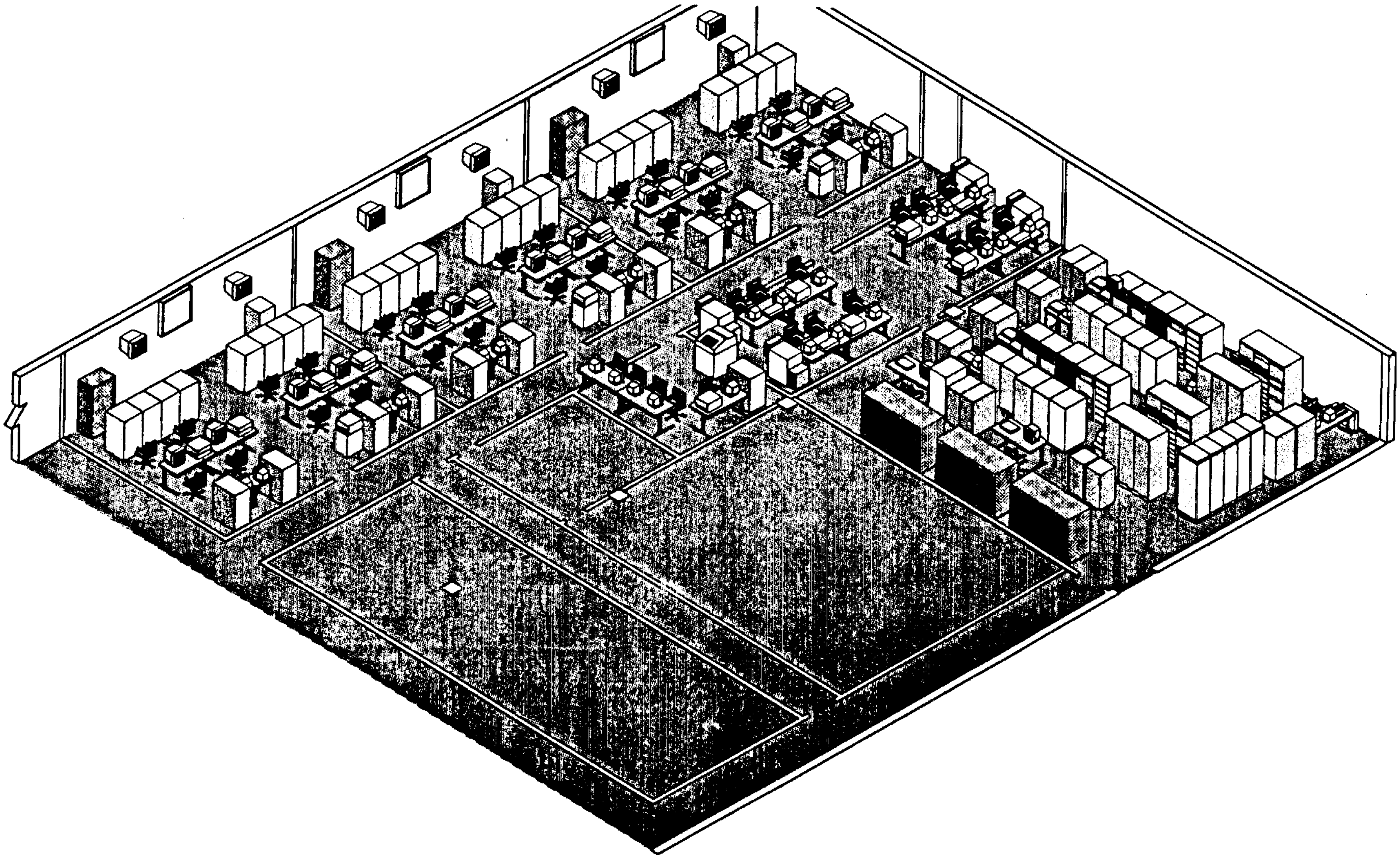
<u>Software Development Station</u> - The SDS provides a system for software development and for creation of operation definition files. Files defining an operation are built by Telemetry and Project Engineers at either the SDS or the TPSS and distributed to the appropriate subsystems during operation initialization. These

files define display formats, EU conversion parameters, stripchart channel assignments and telemetry channels to be processed, as well as providing assignment of telemetry IDs to workstations.

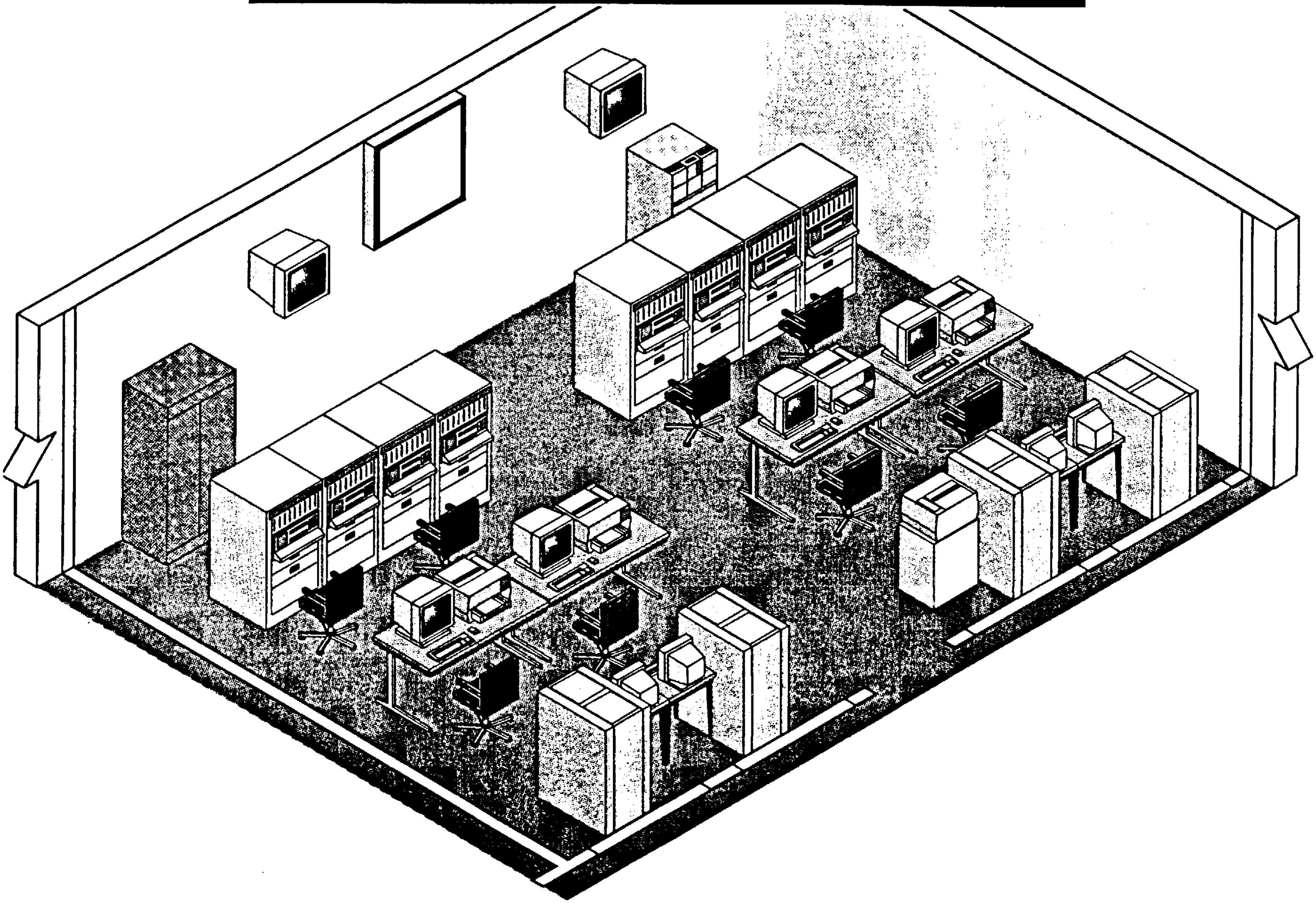
TPS ARCHITECTURE



TPS FACILITIES



TPS OPERATIONS CONTROL ROOM



TPS PERFORMANCE SUMMARY

- **SUPPORT 4 SIMULTANEOUS MISSIONS**
  - Anticipate 780 Flights Per Year

- **SINGLE MISSION REQUIREMENTS**
  - Four 10 Mbit PCM (Embedded 1553)
  - Multiplexed FM (20 Channels / 300,000 sps)
  - Analog to Digital FM (32 Channels / 500,000 sps)
  - Two PAM (128 Parameters / Stream / 125,000 sps)
  - 16,000 Measurements / 500,000 sps / 400,000 EUC

- **FACILITY REQUIREMENTS**
  - One Floor: 1 Computer Room, 3 Mission Control Rooms
  - Any Front End to Any or All Display Rooms
  - 100,000 sps Data Transfer to/from Cyber

TPS SOLUTION CHARACTERISTICS

- **FIBER OPTIC INTERFACE**
- **FIBER PATCH PANEL**
  - Security
  - Configuration Flexibility
- **CUSTOM CARD DESIGN BETWEEN FRONT END AND HOST**
  - Cyber Conversion
  - Strip Chart Processing and Control
- **USE OF UNIVERSAL MEMORY NETWORK (UMN) - SHARED MEMORY**
  - Simplified Strip Chart Data and Control Issues
  - Solved Cyber Data Conversion Problem
  - Downsized Host Requirement to Enable Use of DEC 6220
  - Enabled Use of DEC VAX in a Real-Time Environment

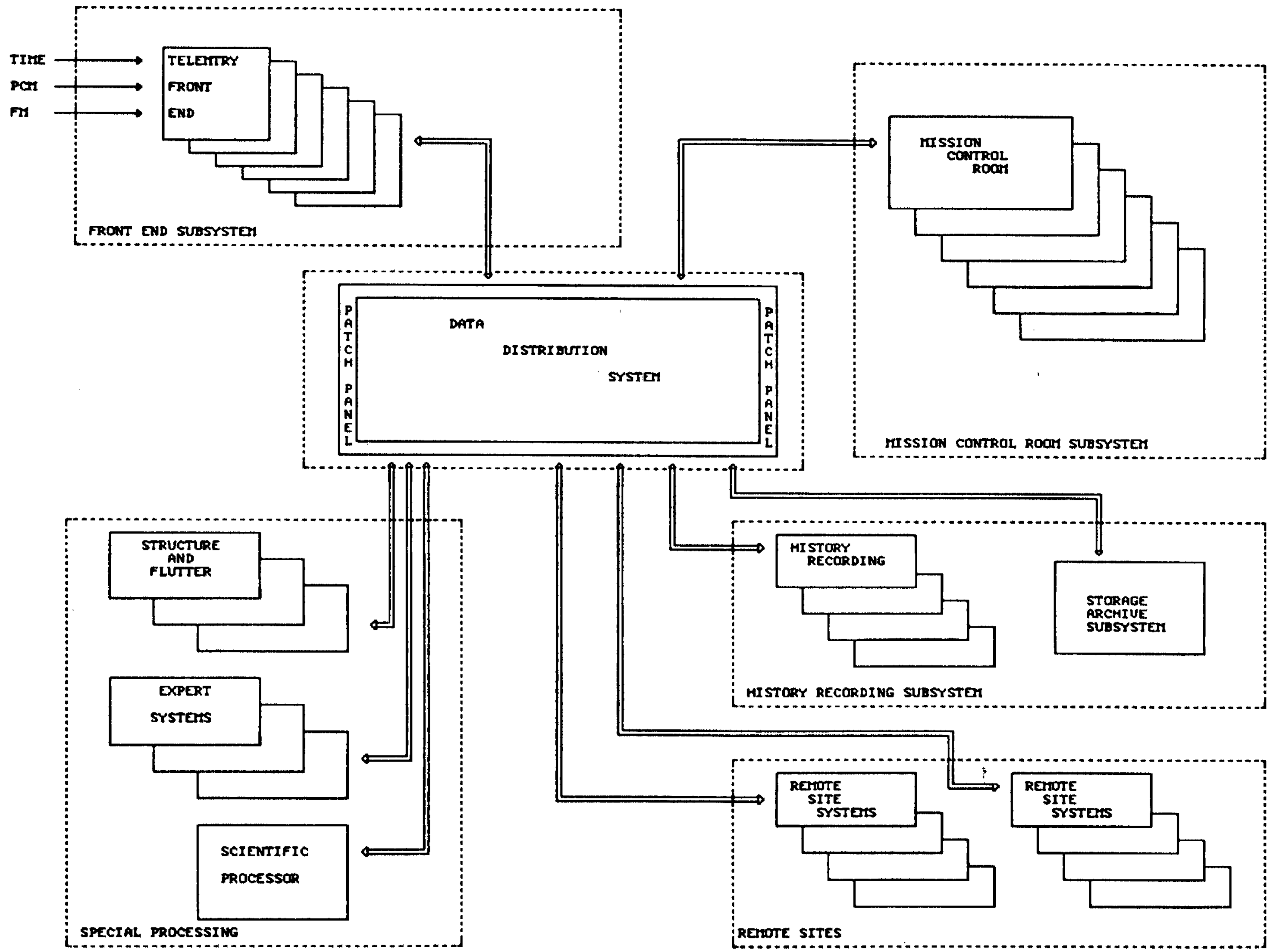
RDSC TELEMETRY SYSTEM CAPABILITIES

INSTALLED SYSTEMS	IFDAPS	B-2 TSF	RTPS III	UTTR	TEST PILOT SCHOOL	TPS
Number of Streams	5	3	6	2	1	4
FM Input (In samples per second)	36 Channels Aggregate 250,000	72 Channels Aggregate 300,000	64 Channels Aggregate 200,000	None	16 Channels Aggregate 300,000	20 Channels Aggregate 300,000
PCM Input	3 Sources 5 MB/Sec per Source	2 Sources 1.2 MB/Sec per Source	4 Sources 10 MB/Sec per Source	1 Source 1.28 MB/Sec	2 Sources 1.2 MB/Sec per Source	4 Sources 10 MB/Sec per Source
Engineering Unit Conversion	20,000 samples per sec.	156,000 samples per sec.	200,000 samples per second	14,000 samples per sec.	156,000 samples per second	400,000 samples per sec.
History Recording (In samples per second)	EU: 20,000 RAW: 35,000	EU: 156,000 RAW: 300,000	EU: 162,000	EU: 14,000	EU: 100,000	EU Untagged: 360,000 EU ID Tagged: 180,000
Maximum Number of Measurands	4,096	10,000	2,000	4,096	4,096	16,312
Graphics Terminals	6 Color	10 Color	2	1 Color	3 Color	4 Color
Alphanumeric Terminals	6	3	6 Color	1	3	4
Strip Chart Pens	128	128	64	32	8	64

HYPOTHETICAL COMPOSITE SYSTEM CAPABILITY

PCM INPUT	FM INPUT	ENG. UNIT CONV.	HISTORY RECORDING	MAXIMUM NO. OF MEAS.	GRAPHICS TERMINALS	STRIP CHART PENS
4 Sources 10 MB/Sec per Source	72 Channels Aggregate 300,000	400,000 samples per sec.	EU Untagged: 360,000 EU ID Tagged: 180,000	16,312	100 - SUN -SGI	256

SEAMLESS ACQUISITION AND PROCESSING



CSC DEVELOPMENT PRINCIPLES

CSC's approach to designing and implementing systems may be defined in three words: involvement, process and automation.

Involvement implies a team made up of representatives of all parties concerned with the success of the system. It is an "egoless" team not concerned with who receives credit for success. Client, integrator, users and other contractors are all involved in defining requirements, goals and user products and interfaces. The desired products and external interfaces are defined and documented along with goals before requirements are written. This is done rapidly with the knowledge that the result will be maintained as a working document that will reach maturity only when the system is complete. This "user" document(s) provides an informed basis for defining requirements. When the "team" agrees that the requirements are as complete as can be reasonably expected, the design phase begins. Just as the contractors and users were involved in the requirements analysis and definition phase, so is the client involved in the design phase. It is equally important to keep engineers, programmers and support staff involved. This is done by keeping them informed on the progress of the project and listening to their ideas on possible improvements to the development process; management has no monopoly on good ideas. Keeping all parties involved engenders enthusiasm for and helps insure success of the project.

Process determines the manner in which the development is managed. The process is defined by a methodology which is tailored to the specific application. It takes full advantage of Commercial Off-The-Shelf (COTS) hardware and software and encourages the use of software that can be transported between systems. The methodology provides for design, code and test standards. It provides for a means of defining the system functions as detailed by the requirements specification and for assigning requirements to system and subsystem components down to the software module or hardware component level. The methodology provides for the mapping of requirements to the lowest level system components and for meticulously defining interfaces at all levels of system design. The methodology provides for breaking a large complex problem into smaller logical pieces that can be recognized as something that the implementor has done before. The more experience the "team" has in a particular discipline, the earlier in the decomposition this recognition occurs and the lower is the development cost.

The facility must always be considered in the total process. CSC develops a Site Preparation Requirements Equipment Installation Plan (SPREIP) for every project. Power supplies, facility layout, exact cable distances, air conditioning and other related items are analyzed and fed into the total development process in order to influence design as necessary and eliminate any surprises when correction may prove very costly. This falls in line with CSC's general development philosophy of identifying interface problems as early in the development phase as possible. Correction of interface problems late in the development phase or in the test phase has been responsible for large cost overruns on many projects.

Automation refers to the application of "tools" to the analysis, design and development processes. A universally recognized tool is Computer Aided Design (CAD) with automatic placement and signal routing for PC components. Tools supporting programmers, such as debugging aids, dynamic and static performance analysis packages, source code maintenance and text editors are readily available. CSC uses these tools to the maximum extent possible and constantly polls the industry for the latest development tools. Configuration management tools have been developed by CSC. CSC uses both their own configuration management tools and those provided by the vendors.

Computer Aided Software Engineering (CASE) tools are available, but not as universally accepted throughout the industry as tools such as CAD and software debuggers. CSC has been using CASE tools successfully for several years. CASE not only provides automation for the design phase, but it integrates design and documentation into a single process, something that is not possible without automation. The problem some developers have with CASE is that they expect the tool to perform the process for them. Before CASE can be successfully applied, the methodology associated with the particular CASE tool must be thoroughly understood. CASE can be applied most profitably if it is networked, giving all developers access to the process narratives and logic diagrams (i.e., data flows, structure charts, etc.). It is also important that the CASE tool provide the user with an acceptable word processing capability and data dictionary. Not all CASE tools contain these capabilities. CSC understands the misgivings voiced by some developers using CASE, but believes that these misgivings are rarely the fault of the CASE tool, but rather the developer's unrealistic expectations. CSC will continue to use CASE and other design and development tools and participate in their expanded use in the industry.

Automation is also used in performance monitoring and tracking estimated vs. actual progress in terms of measurable schedule and cost variances. CSC project managers use tools such as Super Project, Timeline and Lotus to provide objective monitoring of a project's progress. Which tool is used is dependent upon the needs of the project and the specific project manager's personal experience with a particular tool. The importance of these tools cannot be overestimated for the insight they give managers in developing and modifying plans to achieve the original project goals.

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DEVELOPMENT APPROACH

- **TEAM CONCEPT**
  - Continuity
  - Client Involvement
- **OPEN ARCHITECTURE (truly open)**
- **FLEXIBLE METHODOLOGY**
- **AUTOMATION (CASE, CM)**
- **QUANTITIVE MEASUREMENT OF PROGRESS**

SUMMARY

- **SOPHISTICATED CONTROL SYSTEMS CAN BE BUILT**
  - Within Budgetary Constraints
  - Within Schedule Constraints

- **AVAILABLE TECHNOLOGY PERMITS SIGNIFICANT USE OF COMMERCIAL EQUIPMENT WITHIN HIGH PERFORMANCE SYSTEMS**
  - Cost Advantage
  - Risk Reduction

- **FOCUSED CUSTOM DEVELOPMENTS LEVERAGE THE USE OF COMMERCIAL EQUIPMENT**

- **TEAMWORK UNDERLIES EVERY SUCCESS**

MANAGEMENT PHILOSOPHY

- INVOLVEMENT
- PROCESS
- AUTOMATION

"IT IS AMAZING HOW MUCH GETS ACCOMPLISHED WHEN NO ONE CARES WHO GETS THE CREDIT"

Agenda

- SFOC IN JPL's GROUND DATA SYSTEM
- SFOC PROJECT MOTIVATION AND HISTORICAL PERSPECTIVE
- SFOC TECHNICAL DESCRIPTION
- SFOC CHARACTERISTICS VS. COST FACTORS
  - GDS DEVELOPMENT COST
  - RELATIONSHIP TO OPERATIONS COSTS
- SFOC STATUS AND METRICS