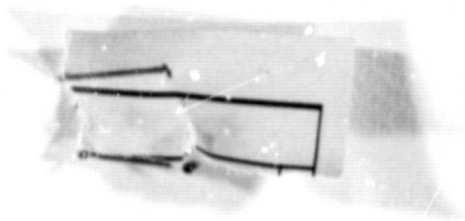


EARTH RESOURCES TECHNOLOGY SATELLITE
FINAL REPORT

18. AUTOMATIC DATA PROCESSING EQUIPMENT PROCUREMENT

PREPARED FOR
GODDARD SPACE FLIGHT CENTER
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
UNDER CONTRACT NAS5-11260

TRW SYSTEMS GROUP

IBM FEDERAL SYSTEMS DIVISION

Itek OPTICAL SYSTEMS DIVISION

EARTH RESOURCES TECHNOLOGY SATELLITE

FINAL REPORT

Volume 18. Automatic Data Processing
Equipment Procurement

April 17, 1970

prepared for

National Aeronautics and Space Administration
Goddard Space Flight Center

Contract NAS5-11260

item 5a

TRW Systems Group
One Space Park · Redondo Beach
Los Angeles County
California 90278

CONTENTS

1. BACKGROUND AND SUMMARY

Sections 7.15.3.2 and 7.15.3.4 of the "Design Study Specifications for the Earth Resources Technology Satellite" require TRW to prepare performance characteristics for the Automatic Data Processing Equipment (ADPE) and to issue RFQ's for the specified equipment, followed by evaluation of responses and selection of proposed equipment subcontractors.

This document describes the procedures followed to comply with this requirement and gives the results together with their justification. Certain portions of the "ADPE Applications/Feasibility Study, Ground Data Handling System," 2 February 1970, are repeated here as necessary background, together with certain data from the "ADP Request for Quotations (RFQ) and Specifications," delivered to GSFC on 21 February 1970.

The basic requirements for the ADPE given in Tables 1-1 and 1-2, relating to the OCC and NDPF computing requirements respectively, were used in the RFQ. GSE computer requirements are given in narrative form in the RFQ. The tables were included in the RFQ and their derivation is discussed in Section 2 below.

RFQ's were issued to 25 companies, of whom 7 expressed an intention to bid and 5 submitted responses. Detailed scoring results and discussion of the selection process will be found in Section 4.

The evaluation process led to the recommendation by the Source Evaluation Board for selection of the following equipment for the ERTS ADPE:

OCC	IBM 360/65
NDPF	IBM 360/85
GSE	XDS Sigma 5

The Source Selection Officer, Dr. C. D. Graves, selected the recommended IBM 360/85 for the NDPF and the XDS Sigma 5 for the GSE, but chose as the OCC computer, the IBM 360/44. The reasons

Table 1-1. Quantitative Requirements for OCC Computer

Function	(1) No. Executed Instructions Per Execution (Less OH)	(2) Freq. of Exec/Day	(3) Instruction Mix Logic (percent)	Comp (percent)	Float (percent)	(4) Peripheral Storage Needs (No. of Bits) Random	(5) Core Requirements No. of Instructions	Bits of Data	(6) Peripheral Devices (No. and Kind)	(7) Data Accuracy Max No. Sig Decimals Digits	(8) Data Transfer Capability/ Execution (No. of Bits)
Ground Schedule	6×10^4	1/2	74	26	8	25×10^7	1.2×10^4	1.3×10^6	Disk/Drum	7	12×10^7
Spacecraft Schedule	16×10^6	4	62	38	35	10×10^7	2.06×10^4	2.4×10^5	Disk/Drum	7	1.1×10^6
Command Generation	16×10^6	4	82	18	23	1×10^8	3.4×10^4	1×10^6	Disk/Drum	7	5×10^5
Message Up Date	1.3×10^7	4	94	6	0.1	15×10^7	2,724	6.2×10^5	Disk/Drum	7	6×10^5
PCM TLM Proc	1×10^9	14	75	25	19	3×10^8	19,442	1.3×10^6	3 Tapes Disk/Drum	7	3.8×10^7
Sensor Coverage	9.9×10^6	1	84	16	19	1×10^8	3,426	1.4×10^6	1 Tape Disk/Drum	7	25×10^6
Display	17,164	200	86	14	9	6.47×10^5	17,037	1.5×10^6	9 CRT	N/A	

Table 1-2. Quantitative Requirements for NDPF Computer

Function	(1) No. Executed Instructions Per Execution (Less OH)	(2) Freq. of Exec/Day	(3) Instruction Mix Logic (percent)	Comp (percent)	Float (percent)	(4) Peripheral Storage Needs No. of Bits Random/Sequential	(5) Core Requirements No. of Instructions	Bits of Data	(6) Peripheral Devices No. and Kind	(7) Data Accuracy Max No. Sig Decimals Digits	(8) Data Transfer Capability/ Execution (No. of Bits)
Attitude Determination	8×10^4	14	60	40	18	10×10^4/0	3370	1×10^4	Disk/Drum	13	8×10^7
Information Management Production Control	20×10^6	250	100	0	0	3×10^9/60×10^6	20K	160K	4 Tapes 6 Disk/Drum	7	1.6×10^5
Bulk Image	1.7×10^8	180	75	25	8	2.84×10^8/0	1658	4×10^6	Disk/Drum	7	1.3×10^8
Precision Image	1×10^9	22	48	52	38	2.84×10^8/0	3946	4×10^6	Disk/Drum	7	1.3×10^8
Display	8000	250	86	14	9	647K/0	8000	1.5×10^6	5 CRT	N/A	

NOTES (Tables 1-1 and 1-2):

Column Headings

1. Number of executed instructions/function execution (less overhead).

   Overhead, i.e., the software operating system is not included in the table figures. The manufacturers must include their operating system requirements.

2. Frequency of function execution/day (8 hours).

   How many times or what fraction of a unit time will this function be used in an 8 hour day.

   This entry could be used to pseudo time-line a days activity to identify loading conflicts.

3. Instruction Mix

   Percent logic instructions branch/compare/load/store/boolean operations, etc.).

   Percent computational instructions (add/multiply, etc.).

   Percent floating point arithmetic involved in logic and computational instructions.

4. Peripheral random storage needs (number of bits, less overhead).

   States number of bits for random access method.

5. Core requirements (less overhead)

   Instructions.

   Data in bits.

6. Peripheral devices required (less overhead).

   Input-output type (e.g., printers, card punch/reader, tape).

   Indicates the number and type of unit.

7. Data accuracy (maximum number of significant decimal digits).

8. Data transfer capability/execution of function (number of bits).

Additional Notes

The ERTS Design Specifications require that the work day length be defined for the OCC and the NDPF as follows:

a) The OCC operates on a 24 hour daily schedule.

b) The NDPF operates on an 8 hour per day schedule.

The data in Tables 1-1 and 1-2 is subject to the comments below:

a) All numbers exclude system overhead for all table elements including peripherals.

b) All data is given in number of bits, except in column 7 which is given in number of significant decimal digits.

c) Instruction count is given in actual number of instructions, not number of bits

d) In the OCC, it is likely that the command generation, message update, PCM processing, and display functions may be run concurrently.

e) In the NDPF, it is likely that the bulk image, precision image, information management, and display functions may be run concurrently.

for this selection are given in Section 5. Briefly, the selection of the 360/85 for the NDPF, together with a reduction in the scope of the OCC computing requirements, made it possible to assign more OCC processing tasks to the NDPF computer and to meet the remaining OCC requirements with a much smaller machine. The resulting total configuration is an approximation to the single-computer option considered throughout the ADPE study and included in the RFQ. Logistic and operational considerations, particularly those for backup capability, made it desirable to have both machines of the same manufacturer and series.

The selected ADPE is therefore as follows:

360/85 with	– 2085-K Processing Unit 2385-I Processor Storage (2 megabytes)
360/44 with	– 2044 G44 Processing Unit (with 131,072 bytes storage)
XDS Sigma 5 with	– CPU 8202 Memory: 2 sets 8251 2 sets 8252

Volume 14 of the Final Report presents the GDHS design with a detailed description of the ADPE configuration.

2. DEVELOPMENT OF TIMING AND SIZING REQUIREMENTS

The procedures and techniques for developing the timing and sizing requirements for the OCC/NDPF computers, including the computer program written for this purpose, are described in document EBC-G149, "ADP Application/Feasibility Study, Ground Data Handling System," 2 February 1970. Attachment B to that document is an extensive listing of timing and storage data for some 150 routines of the OCC and NDPF software systems, estimated for three different sizes of computer systems.

The quantitative results are central to the design of the baseline GDHS configuration. The data input to, and resulting from, these studies were therefore in formats appropriate to engineering design and decisions. A particular question requiring an early answer was "What size computer system is required to support, respectively, OCC and NDPF functions?" The best tool available to treat this problem requires that a specific computer be chosen, then one computes the time required to process a particular routine on this specific machine. Finally, the aggregate time needed for computing all appropriate routines is modified by factors determined from an individual analysis of the overall system (OCC or NDPF) function.

The final output format is in the form of: N minutes per day are needed to perform a function, such as PCM telemetry processing, on a specific machine.

Because of the competitive nature of the computer manufacturing business, there are, however, several machines essentially identical to the particular one which was selected for convenience. The baseline design can be carried forward with quantitative assurance of the computer systems required without, in any sense, choosing a particular manufacturer.

To ensure maximum competition calling forth the insight and experience of companies seasoned in minimizing costs for a specified level of

performance, we chose to issue Requests for Quotation (RFQ) wherein the performance requirements were given in fundamental, non-machine-particular units, not only adequate for defining completely the necessary computer system, but also in both such detail and specially chosen categories that real latitude exists for creative system engineering. The most important design consideration apparent from the data presented (see Table 1-1) is balancing the input-output capacity of the NDPF computer with the very large CPU capacity required.

3. RFQ ISSUANCE AND RESPONSE PROCEDURE

The sequence followed in obtaining bids for the ERTS ADPE was as follows:

February 9, Publication of announcement in Commerce Business Daily

February 11, Prospective bidders' orientation meeting

February 20, RFQ issued

February 25, Preproposal supplier conference

February 26, Deadline for statement of intent to respond

March 16, Proposal due date

At the same time (5 February) the announcement was sent to the Commerce Business Daily, a copy of the announcement was sent by TWX to the list of suppliers shown in Table 3-1. The table indicates which of these suppliers were represented at the 11 and 25 February suppliers' conferences, which received RFQ's, which notified TRW of intent to bid, and which submitted bids. RFQ's were issued to a few companies not listed, but no bids were received from any of them.

Questions and answers at the 25 February suppliers' conference, and exchanged subsequently by TWX, are listed in Table 3-2.

Table 3-1. Suppliers Solicited for ADPE

	Meeting 2/11	Meeting 2/25	Rec'd RFQ	Intent to Bid*	Submitted Bid
Xerox Data Systems, Inc.	X	X	X	X	X
Systems Engineering Laboratories, Inc.	X	X	X	X	X
Honeywell, Inc.	X				
Control Data Corporation	X	X	X	X	X
Applied Dynamics, Inc.					
RCA Corporation			X	-	
Berkeley Scientific Laboratories, Inc.					
Vidar Corporation			X		
Agrippa-Ord Corporation					
Digital Scientific Corporation			X		
Westinghouse Electric Corporation	X		X		
Hartman Huyck Systems Company, Inc.					
Electro Mechanical Research, Inc.		X	X	X	
Digital Equipment Corporation					
Decision Control, Inc.					
Varian Data Machines	X		X		
Lockheed Electronics Company			X		
Electronic Engineering Company of Calif.					
International Business Machines	X	X	X	X	X
Univac	X	X	X	X	X
Burroughs Corporation	X	X	X	X	
General Electric Company	X	X	X	-	
Computer Industries, Inc.					
Eldorado Electrodata Corp.					
Dynalex					
The Wright Company					
K-G Electronics, Inc.					
General Dynamics	X		X		
GES Industries					
Eastronics					
Mitron Systems					
Hydro Systems					
Ampex Corporation					
Systems Concepts, Inc.					
Computer Operations, Inc.					
Systron Donner Corporation					
Astrodata, Inc				-	
Comtech Corporation					
Electronics Laboratory for Electronics					
Raytheon Company	X		X	-	
Jervis B. Webb Company					
Computer Network Systems Corp.					
Daconics	X		X		
Civil Systems, Inc.					
AIL-A Division of Cutler-Hammer					
Contronics					
Systems Data, Inc.			X		
Computer Management Corp.					
Spectro Systems, Inc.					
Pacific Radionics, Inc.					
Natel Engineering Company Inc.					
Datum, Inc.			X		
Monitor Systems			X		
Computer Applications, Inc.					
Universal Systems, Inc.					
Hewlett-Packard	X		X		
Philco-Ford Corporation				-	
C. G. S. Scientific Corporation				-	
Executive Electronics					
IRA Systems, Inc.					
National Scientific Laboratories, Inc.					
Metric Systems Corporation				-	
ABA Tool & Die Company, Inc., of Florida					
National Cash Register Co.					
Data Products Corporation					
Datacraft Corporation	X				
Datacom, Inc.					
Compunetics, Inc.			X		
Electronic Sales Associates					
Progress Electronics Company of Oregon	X		X		
Electronic Marketing Associates					

*An entry of a dash (-) in this column indicates notification to TRW of a decision not to bid.

Table 3-2. Questions and Answers from Suppliers' Conference and Later Correspondence

Proposal Reference and Question	Answer
Page A3, Section 4.1 -- "Requirement for 6 External Devices". What is the data transfer rate requirement for these devices? Can mux channel handle them? Any need for high speed selector-type channel?	High speed selector-type channels will be required to satisfy the data transfer rates of these devices and the 6 external devices referred to on Page B3, Section 4.1.
Page VIII and IX, Column Heading (8) -- "Data Transfers Capability/Execution of Function (Number of Bits)". Please elaborate! Input-output channel transfer rate?	The product of column 2 and column 8 is the total number of bits of data that the associated function (column 1) will transmit to and/or from the device(s) shown in column 6 in 1 day (8 hours for NDPF, 24 hours for OCC). Since the vendor is responsible for selecting the specific type and model of device shown in column 6, he also defines the input-output channel transfer rate.
Page B-5, Section 5.7 -- "Communications Interface." How many lines? What mix of speeds? Aggregate transfer rate?	Only one line at a time. The data rates will be in the 1 kbyte/sec to 50 k byte/sec range.
What are the widths of data paths (in bits) and data rates for the six special-purpose devices on both NDPF and OCC?	At this time, exact specifications are not known. However, high-speed selector-type channels with normal path widths using off-the-shelf channel adaptors will suffice.
Please give us a further explanation of the meaning of column 8 of the tables.	The product of column 2 and column 8 is the total number of bits of data that the associated function (column 1) will transmit to and/or from the device(s) shown in column 6 in one day (8 hours for NDPF, 24 hours for OCC).
A recent question was "What are the widths of data paths (in bits) and data rates for the six special-purpose devices on both NDPF and OCC?" The answer stated that exact specs were unknown, but high-speed selector-type channel with normal path widths using off-the-shelf channel adapters will suffice. What is a normal path width, i.e., how many bits, what specifically is an off-the-shelf channel adapter?	Manufacturer may supply a standard high-speed selector channel oriented to character (or byte) bit requirements in accordance with his equipment. TRW will supply special devices and interface electronics to match the characteristics of the channel supplied.
High-speed processors are extremely sensitive to the degree of optimization of the code - especially in highly repetitive closely packed loops. Can TRW provide one or more kernels of code representative of small (100 instruction) loops that are typical of the code to be proposed in the "bulk image" and "precision image" application on the NDPF so that the bidders can provide benchmark timing on these and equivalent but optimized versions.	No, TRW will not provide representative kernels of code.
If NDPF and OCC requirements are combined as in Lot D, will addressability to 6 or 12 special external devices be required? (Section 4.1, Pages A3 and B3.)	Twelve (12)
Under Lot E, is addressability to only 6 special external devices required or 18?	Six (6)
What are peripheral requirements under Lot E?	Same as Lot A
If under Lot D, the NDPF and OCC requirements are combined, how many magnetic tapes are required, i.e., are they additive?	Twelve (12)
Section 4.5, Page B4, states 9 CRTs are required, yet Table 1-1 lists only 6; which is correct?	Nine (9)
Tables 1.1 and 1.2 list only 4 tapes for NDPF and 4 for OCC, yet page A5 states eight (8) and page B4 six (6), accordingly; which is correct?	The numbers in Tables 1.1 and 1.2 show the number of tape decks required by each NDPF or OCC function. The numbers on pages A5 and B4 show the total requirement which is inclusive of the requirements given in Tables 1.1 and 1.2.

4. PROPOSAL EVALUATION

4.1 PROPOSAL EVALUATION CRITERIA

The following excerpt from the RFQ is presented here as background to the discussion of proposal evaluation.

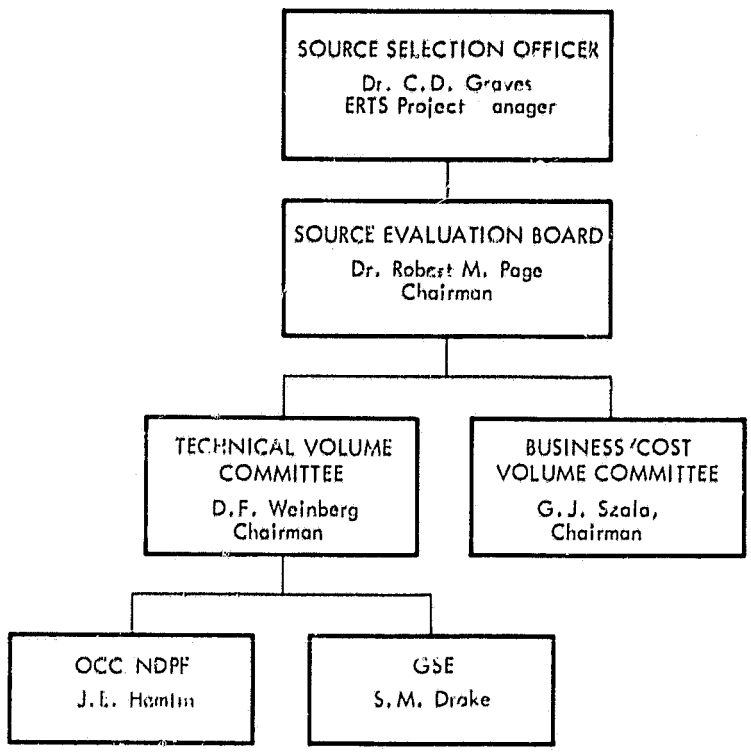
> "The technical specifications for this RFQ transmittal have been developed by TRW SYSTEMS GROUP to array the significant requirements of the NDPF, OCC and GSE computing systems. The three specifications are presented in uniform order so that the characterization of the requisite hardware and software is simplified. To assist TRW SYSTEMS in the subsequent technical evaluations, it is requested that respondent proposals also be itemized in a sequence identical to the specifications format. This arrangement will permit the interpretation and responsive methodology of each manufacturer to be objectively and meaningfully assessed.
>
> "TRW SYSTEMS has concurrently measured each of the specifications in accordance with its relative functional importance to the overall ADPE system performance. These measurements will, in turn, be used as weighting factors applied consistently and without variation to all proposals received under this RFQ. The assignment of these weighting factors will serve as the basis of TRW SYSTEMS' quantitative scoring method. All offerors, of course, must fulfill the minimum specified requirements in order to receive evaluation consideration. As an indication of the relative importance of the factors, the following should be considered:
>
> a) The hardware factor is considerably more important than the software, supporting services, and business factors.
>
> b) The software is the second most important factor.
>
> c) The supporting services and business factors are least important.
>
> Bearing the above in mind, the factors for evaluation are as follows:
>
> a) Hardware - The equipment aspects of quality of design and performance, reliability, and convenience of operation with emphasis on central processor functions, memory characteristics, input-output capabilities, and peripheral devices.
>
> b) Software - System, language, utility, and diagnostic programs, as specified, with regard to comprehensiveness, effectiveness and adequacy of documentation for the user.

c) Services & Business Responsiveness - Supporting services, as required or offered, including the provisions for acceptance testing. Offeror's ability to meet the stated delivery schedule and the clarity and adequacy of the proposal documentation.

d) Cost - The total cost of proposed systems meeting the minimum requirements in areas a, b, and c, above, together with the general qualifications of the offeror."

4.2 EVALUATION PROCEDURE AND ORGANIZATION

The organization established to evaluate the ADPE proposals, chaired by Dr. Robert M. Page, Assistant General Manager, Software and Information Systems Division, was as follows:



For the OCC/NDPF computers, the Technical Volume Committee consisted of five members with extensive computer programming, operation, and application experience. Because of the short evaluation period and the large amount of material, each of the proposals was read by two members of the committee rather than by all. Two members who might have biases resulting from their backgrounds in favor of one supplier were not assigned that proposal for evaluation. When the individual scorings were complete, the committee met as a whole to discuss the results and arrive at a joint decision. The purpose of this meeting was first, to let the two evaluators of each proposal state the reasons for any discrepancies in their scoring and second, to ensure that the same standards were being applied by all evaluators to each element being scored.

The scoring process up to this point did not take into account the weighting factors for the elements being scored. A sample scoring work sheet set used by the evaluators is included as Attachment A to this volume. It will be noted that there are some 90 elements to be evaluated for each proposal. At its joint meetings, the committee determined that these elements could logically be grouped into a smaller number with a single score for each group of items. It was evident that the scores for different elements within the groups tended to be very similar. The final list of scored items consists of 22 hardware, 10 software, and 7 support services. These 39 items were the criteria to be evaluated.

During the discussions held by the full committee, standards were agreed upon with respect to numerical scores above and below the "industry average" of 50. These standards can most easily be illustrated in relation to such quantitative measures as computing speed and memory capacity, but were applied qualitatively to all rated elements of the proposal. The value of "extra" features was necessarily determined by the exercise of technical judgment. The agreed-upon interpretations of numerical scores are illustrated in terms of hours of CPU operation required to handle the specified 8-hour load (for the NDPF) or 24-hour load (for the OCC), as follows.

Score	Interpretation
80 or above	Clearly exceeds requirements by a wide margin, but excess capacity has potential value to the GDHS. Example: NDPF computer handles 8-hour load with less than 2 hours CPU time; OCC computer handles 24-hour load with less than 8 hours CPU time.
60 to 70	Exceeds requirements by a comfortable margin that is greater than that normally expected. Example: NDPF computer handles 8-hour load in 4 hours; OCC computer handles 24-hour load in 12-15 hours CPU time.
50	The "industry average"; i.e., what would normally be expected of a computing system in the given respect. Example: NDPF computer handles 8-hour load in 6 hours; OCC computer handles 24-hour load in 18 hours.
30 to 40	Marginal in the given respect; does not come up to industry average but might be considered with some compromise in other design features or modification in the system. Example: NDPF computer requires more than 7 hours to handle 8-hour load; OCC computer requires more than 20 hours to handle 24-hour load.
20	Has some of the required capability, but far less than required. Example: NDPF computer requires 10 hours to do 8-hour load.
0	Clearly fails to meet the requirement.

Weighting factors were assigned to the 39 scored items and submitted to the Source Evaluation Board for approval (independently of the scores themselves). The same weighting factors were used for the OCC and NDPF computers. The committee determined that the requirements for the two systems, although quantitatively different, were so similar in nature that different sets of weighting factors were not needed. The design requirements in each case were directly reflected in the quantitative specifications of the RFQ.

When the scoring process was completed, the scores were multiplied by the assigned weights, summed, for hardware, software, and support services, and normalized to a scale of 0 to 100. The Technical Volume Committee then transmitted its findings and recommendations to the Source Evaluation Board.

In parallel with this evaluation, the Business/Cost Volume Committee was conducting its evaluation of those volumes. It was found that the only significant basis for comparison was the quoted costs themselves. No important differences were found with respect to the terms and conditions or other requirements of these volumes. The cost figures were transmitted to the Source Evaluation Board to be combined with the recommendations of the Technical Volume Committee. The Source Evaluation Board, consisting of five senior managers with extensive computer system experience but unconnected with the ERTS project, selected a preferred supplier and submitted this recommendation, with supporting data, to the Source Selection Officer.

4.3 RESULTS OF THE TECHNICAL EVALUATION

4.3.1 OCC and NDPF Computers

The unweighted scores are listed in Table 4-1, together with the weights. Definitions of the Lots listed across the top are given in the RFQ. Briefly, the lots are as follows:

Lot A — NDPF Computer
Lot B — OCC Computer
Lot D — Single computer for OCC/NDPF
Lot E — A computer with 3 times the capacity of Lot A

Table 4-1. Results of Proposal Scoring

Lot	A			B					D	E		
Scored Item	IBM	CDC	Univac	IBM	CDC	Univac	XDS	SEL	CDC	IBM	CDC	Weight
Hardware												
1. Standards	40	50	0	40	50	0	0	0	50	40	50	1
2. Production computer	45	50	10	55	50	30	55	0	50	0	10	1
3. Word length-accuracy	50	60	45	50	50	50	50	50	60	50	60	25
4. Instruction repertoire	50	40	45	50	40	45	60	60	40	50	40	35
5. Speed	65	30	0	50	70	60	0	60	0	65	70	100
6. Core size	50	40		40	40	40		0			40	95
7. Core expansion	50	0		50	0	0					0	20
8. Parity checking	60	30		50	30	50					50	2
9. Core modularity	50	50		50	50	50					50	20
10. Core protect-segmentation	50	50		50	50	50					50	40
11. Power failure protection	10	10		10	10	50					10	2
12. Channel/channel adaptation	50	50		50	50	20					50	75
13. Subordinated input-output control	60	60		60	60	50					60	75
14. Interrupts	40	50		40	50	50					50	25
15. Control console	55	55		50	55	45					55	10
16. CRT/keyboard	40	45		40	45	35					45	15
17. Line printer	55	50		55	50	50					50	3
18. Card reader/punch	65	45		65	45	50					45	3
19. Tapes	60	40		60	40	50					40	45
20. Random access storage	50	35		60	35	30					35	50
21. Mechanical/electrical installation	40	40		50	40	50					40	1
Software												
21. Operating system	30	40		30	40	50					40	100
22. Multiprogram control	50	55		50	55	50					55	100
23. Manage peripheral units	50	50		50	50	50					50	100
24. Reconfiguration ability	50	50		50	50	40					50	20
25. Loader	80	30		80	30	70					30	80
26. File maintenance	60	50		60	50	55					50	70
27. Debugging aids	50	50		50	50	50					50	40
28. Assembler	50	50		50	50	50					50	60
29. FORTRAN compiler	50	45		50	45	60					45	60
30. Alternate language	50	50		50	50	0					50	10
Support Services												
31. Hardware documentation	50	50		50	50	50					50	40
32. Software documentation	50	50		50	50	50					50	100
33. Support programmers	60	30		60	30	40					30	80
34. System training	60	50		60	50	50					50	40
35. Diagnostics	60	60		60	60	40					60	100

Lot C is the GSE computer discussed in Section 4.3.2. In all cases, the term "computer" means the entire set of computing equipment, peripherals, software, and support services to meet the specified requirements. None of the proposals included any response to two of the support services items (reliability requirements and acceptance testing); these items were therefore not included in the evaluation and will have to be negotiated at the time of contract award.

The summed and normalized scores are listed in Table 4-2. Lot D is not shown because the computer capacity was marginal and the proposed single-computer configuration was considered not acceptable.

The blank entries in Table 4-1 are for proposed systems that were judged so significantly nonresponsive in terms of critical technical performance characteristics that such systems should clearly be rejected. Scoring of these proposals was stopped upon such a determination.

Table 4-2. Unweighted Scores of Acceptable Proposals by Category

	A		B			E	
	IBM	CDC	IBM	CDC	Uni	CDC	Category Weight
Hardware	54	43	51	49	43	49	56
Software	52	46	52	46	53	46	31
Support Services	56	48	56	48	45	48	6

Of particular importance are the weighted technical scores for the NDPF computers:

a) IBM 360/85 53.5

b) CDC 6600 44.3

4.3.2 GSE Computer Technical Evaluation

The procedure for evaluation of the GSE computer proposals was somewhat different from the OCC/NDPF case. Only four proposals were received, and these were smaller in size than the others. Each member of the subcommittee thus read all of the proposals. Also, the low quality of the proposals made a formal scoring procedure difficult for all attributes listed in the RFQ.

Proposals were received from XDS, IBM, SEL, and Univac. The machines proposed were the Sigma 5, 360/44, 840, and 1230, respectively. Numerical ratings were assigned to the hardware and software items only (3 hardware, 1 software); narrative comments are provided for the other items.

The items rated for hardware and software, together with the weighting factors, are listed in Tables 4-3 and 4-4. Ratings were on a scale of 0 to 80: 80 indicated a significant advantage of the rated feature, 50 acceptable, 40 marginal, and 0 unacceptable. The summed and normalized (to 1.00 for the highest score) results are shown in Table 4-5. Comments on the items not rated numerically follow:

- Physical Requirements. Univac was judged highest in its ability to meet the problems involved in the testing environment, followed by IBM, XDS, and SEL. No bidders met the RFQ temperature specification. SEL was judged marginal on the basis of TRW experience with comparable SEL equipment.

- Reliability Requirements. XDS and IBM did not respond, and the SEL response was found to be at variance with TRW's experience.

- Documentation and Training. Rank order for this requirement was judged to be IBM, XDS, SEL, Univac. SEL and Univac were marginal and poor.

- Acceptance Testing. IBM and XDS did not respond. SEL and Univac indicated accord with the terms in the RFQ.

Overall technical evaluations of the four responses were as follows:

- XDS. Was rated below acceptable only for its CRT Display Unit and Handler. Environmental aspects were rated marginal. Software appeared to be the most complete, excelling in its assembler, library, and diagnostic aids. The XDS Sigma 5 also offered considerable advantages in memory speed, instruction set, and ability to use the 64K memory.

- IBM. Was downgraded on its CRT Display Unit and Handler, the need for base registers to address core, interrupt timing, and the disc unit used for system storage. Strong features were the assembler, instruction set, index-arithmetic registers, and documentation.

- SEL. Was seriously downgraded for its lack of existing input-output handlers, documentation, and the lack of reliability of

Table 4-3. Hardware Evaluation Factors and Weights

Factor	Weight
Buffered data channels	15
Digital input/output	15
Instruction set	10
Magnetic tape/disc/drum	7
CRT	5
Line printer	5
Shift operations	5
Interrupt timing	5
Priority interrupts	5
Index registers	4
Hardware	3
Addressability	2
Memory expandability	2
Word length	2
DAC	2
Indirect addressing	2
Memory and CPU speed	2
Arithmetic unit	1
General description	1
Card reader	1
Teletype	1
Computer console	1
Privileged instruction mode	1
Round and carry	1
Parity checking	1
Memory size	1
Total	100

Table 4-4. Software Evaluation Factors and Weights

Factor	Weight
Input-output handlers	20
Interrupt handlers	
Peripheral input/output handlers	
Input/output control system	
Digital input/output handler	
CRT display handler	
DAC handler	
Operating system	20
Assembler	15
Library	13
Loader	10
Dump	8
Source editor	5
Fortran	4
Report generator	2
Copy	2
Sort	1
Total	100

Table 4-5. Summary of Normalized Hardware and Software Ratings

Hardware		Software	
XDS	1.00	XDS	1.00
IBM	0.90	IBM	0.83
SEL	0.84	SEL	0.72
Univac	0.78	Univac	Unable to rate

SEL equipment currently used by TRW on the Model 35 spacecraft. Problems have been noted with priority interrupts, line printer, disc and tape decks in the operational environment. No strong features were noted.

- Univac. The software section of the Univac proposal was very poorly written. It was found impossible to evaluate the software from the description provided. Priority interrupts, shift instructions, and documentation were also judged poor. This was the only machine, however, to approach meeting the environmental requirements and it was also highly rated on electrical and mechanical requirements.

Either of the two top-rated computers, XDS and IBM, appear to be capable of performing the task. XDS was rated higher in both the hardware and software ratings, with IBM slightly higher in the Physical Requirements and Documentation categories. The third choice in the hardware and software ratings, SEL, was rated very low in the Physical Requirements and Documentation categories and appears to be a very doubtful choice. The Univac proposal was so vague in the software section that it was impossible to evaluate.

5. DISQUALIFICATIONS AND OTHER MAJOR CONSIDERATIONS (OCC/NDPF)

5.1 NDPF EQUIPMENT

At the first pre-RFQ briefing for potential bidders, the acceptable approach to meeting NDPF image processing requirements was discussed. It was explicitly stated by TRW that proposals wherein array processors were presented as necessary adjuncts to the basic digital computer were not desired. The reason given was that such a hardware approach was not compatible with the baseline design goals of large and flexible capability. Moreover, the forte of such special front ends was in large volume applications for techniques such as image enhancement, that we judged inappropriate for TRW's data processing design. The RFQ specifically called for "a general purpose digital computer currently in production," with "significant operational use of closely identical systems to be documented in the proposal."

5.1.1 Univac

The NDPF computer configuration proposed by Univac was an 1108 with a 3004 Array Processor. Without the array processor (1108 alone) the required NDPF tasks specified for completion in 8 hours could not be done in a 24 hour day. With the array processor utilized in the most effective manner for doing "proposal-input type calculations," a machine loading of over 90 percent (7.22 hours) is required according to Univac analysis. We then have a technically nonresponsive proposal which at best offers an unacceptably small margin of apparent reserve. This proposal was disqualified as being nonresponsive in the category of memory and CPU speed. (Reference: RFQ, p. 42, Section 3.4.) Moreover the proposal did not document "significant operational use of closely identical systems" (Reference: RFQ, p. A2, Section 3.1). No instance of such an operational system was given.

5.1.2 CDC

The NDPF computer system proposed by CDC was a CDC 6600. The proposal states that a CPU utilization of 86 percent is required by the RFQ specifications. This number was confirmed by a TRW developed computer timing program. The 14 percent margin estimate was judged marginally

low. This evaluation is reflected in the score of 30 given for memory and CPU speed for this machine. The 6600 met the required performance level as a "standard product, general purpose, binary digital computer, currently in production," and with significant operational use of closely identical systems. If the CDC 6600 had been screened out from further consideration on the basis of having inadequate reserve computing capacity, there would have remained no competitor to the IBM 360/85 for the NDPF application.

5.1.3 Lot E

The Lot E computer was characterized as having three times the computational power of the basic NDPF computer. The RFQ stated, "This option is being considered in order to evaluate the cost and delivery impact of a significant increase in the sophistication of image processing.

In requesting a proposal for such a system, however, there was no waiver of the requirement, Section 3.1 of the RFQ, that the "computational system must (sic) be a standard product, general purpose, binary digital computer, currently in production, and a significant operational use of closely identical systems must be documented in the proposal."

The IBM 195 proposed for Lot E was judged to be nonresponsive to Section 3.1 and was disqualified as a candidate for Lot E.

On the other hand, the CDC 7600 was deemed to satisfy Section 3.1 of the RFQ to the extent that this proposal received a full technical evaluation.

5.1.4 Lot D

The only proposal for a Lot D system was the CDC 6600, which was also the configuration proposed for Lot A. In the Lot D application where both NDPF and OCC functions are supported on one machine, the CPU load goes to 92.5 percent from the 86 percent required for the NDPF (Lot A) application.

Experience has consistently shown that a nominal reserve as small as 7.5 percent will, in practice, turn out to be a "negative reserve." Consequently, this proposal for Lot D was deemed not meriting further evaluation.

5.2 OCC EQUIPMENT

The procedure used by the Technical Volume Committee, as reflected in the results of Table 4-1, led to quick identification of proposed systems that were so significantly nonresponsive in terms of critical technical performance characteristics that they should be rejected. Scoring of these proposals was stopped when this finding was made. The XDS and SEL proposed configurations were eliminated on this basis.

XDS. In the case of XDS the configuration proposed was a dual Sigma 5. Using XDS-furnished data for execution times of basic operations, TRW timing analysis demonstrated that the proposed system would require a minimum of 22 hours per day to perform the OCC functions, thus leaving a nominal performance reserve of about 8 percent. This is an extremely marginal reserve, and there were no compensating performance factors. The XDS configuration was judged too slow to support the specified OCC tasks, and was therefore eliminated as a candidate system.

SEL. A system 86 was proposed by SEL, and found to be significantly nonresponsive to the RFQ requirements for size of high-speed memory. The proposal was judged nonresponsive.

The remaining three proposals (IBM, CDC, Univac) were subjected to the complete scoring process with the results given in Section 4.2. The selection of the IBM 360/44 is based on the following considerations:

- The most economical solution for the computational needs of the GDHS was determined to be a highly integrated two computer complex, with the non-real time OCC functions being supported by the computer sized to support the NDPF activites.
- Selection of the IBM 360/85 as the NDPF computer, with 50 percent reserve in CPU capacity after meeting the NDPF requirements.
- The essential requirement for computer-supported backup to critical observatory-related OCC functions and the consequent necessity for two totally compatible computers.
- The quantitative analysis showed that the IBM 360/65 would have been excessive in capacity and cost.

Evaluation of the GDHS study results after release of the RFQ indicated that the PCM telemetry processing fundamental to observatory command and control could be supported with a significantly simplified software approach, as compared to the previous design. Additional software simplification in the OCC was achieved by eliminating the ground scheduling software, mission planning software (other than event scheduling), and most software modeling. In the aggregate, these changes are smaller in magnitude than the reduction in telemetry processing requirements.

In the light of these reduced requirements, the OCC required a substantially less powerful computer than that specified in the RFQ. Since the IBM 360/85 was a clear-cut choice for the NDPF compatibility requirements for backup operation led to selection of another computer in the 360 series. The 360/44 was found to be adequate for the reduced OCC requirements, when configured together with the 360/85 in the NDPF. This combination offers a very economical configuration with outstanding flexibility and growth potential.

The selection of the 360/44 for the OCC provides to the Government a minimum-cost ADPE system for the GDHS that is entirely suited to the needs of the ERTS program.

Volume 16 of the Final Report contains the analysis that substantiates the choice of the 360/44 for the OCC.

ATTACHMENT A

OCC & NDPF Proposal Evaluation Work Sheet

Bidder: _____ Evaluator: _____ Date: _____

Scoring Group Number*	Reference RFQ Section	Item	R = Required O = Optional	Comments or Reference Notes	Score
H1	2, 1	Meet current standards for FIPS PUB compatibility with input/ output media - or	R		
	2, 1, 1	otherwise outline time and cost - for future conversion	O		
H2	3, 1	General			
	3, 1, 1	Standard Product	R		
	3, 1, 2	General Purpose	R		
	3, 1, 3	Binary Digital Computer	R		
	3, 1, 4	Currently in production	R	Not prototype or first production system - should have replacement parts/units and established maintenance/technical support	
	3, 1, 5	Significant operational use	R		
	3, 1, 6	Closely identical systems			
H3	3, 2	Word length	R	Should be compatible with register structure of machine and data transfer means	
	3, 2, 1	Decimal accuracy	R		
	3, 3, 1	Double precision, floating point	R		
		or			
	3, 3, 1	Single precision	O	Accuracy of 13 decimal digits (52-60 bits)	
H4	3, 3, 2	Instruction repertoire must include instructions for data handling down to "character" and bit	R	Evaluate instructions set for arithmetic, logical and data handling operations including control of special devices	
H5	3, 4	Memory and CPU Speed	R	Exclusive of O, H,	
	3, 4, 1		R	Exclusive of O, H,	
H6	3, 5	Memory Size OCC 50K instructions 12, 5 M bits data NDPF 28K instructions 5 M bits data	R	Exclusive of O, H,	
H7	3, 6	Memory expansion capability	R		
	3, 6, 1	Impact on installation facility	R		
H8	3, 7	Parity checking or core storage transfers	R		
	3, 7,	Hardware, Parity error interrupt & feature	O		
H9	3, 8	Modular (core storage)	O		
	3, 8, 1	Addressable (by blocks)	O		
H10	3, 8, 2	Core Storage protect feature	O		
	3, 9	Capability to prevent interference among users	R		
H11	3, 9, 1	Protection against power failure	R		
H12	4, 1	Channel - high speed bus - for non-standard peripheral devices - 6 minimum having data transfer paths and interconnect control logic and cabling	R		
H13	4, 2	Subordinated control for block transfers of high rate date sets, up to 32K words	R		
H14	4, 3	Interrupts - Standard peripheral devices	R		
		Special devices (6)	R		
		Priority Scheme	R		
		Save control info and restore previous operations	R		

*H denotes Hardware
S denotes Software
SS denotes Support Services

OCC & NDPF Proposal Evaluation Work Sheet (Continued)

Bidder:_____ Evaluator:_____ Date:_____

Scoring Group Number	Reference RFQ Section	Item	R = Required O = Optional	Comments or Reference Notes	Score
H15	4.4	Console: Bootstrap program loading Display control registers or core storage locations Manually single-step instructions Display interrupt system and halt status	R R R R		
H16	4.5	CRT/Keyboard entry units - NDPF 5 OCC 9 Self-refreshing Single Screen 10" x 12" viewing area 1000 character 80 characters/line	R		
H17	5.2	Line printers 750 lines/min. maximum 64 character set 132 character, line length minimum Total output must be 2000 lines/min. minimum	R		
H18	5.3	Card reading unit 500 cards per minute minimum 80 column - column binary and Hollerith	R		
	5.4	Card punching 300 cards per minute minimum 80 column - column binary and Hollerith	R		
H19	5.5	Magnetic Tapes (8 - NDPF) (6 - OCC) 90 KB character rate 9-track read/write heads 800/1600 switchable density modes Checking-read back check while write with vertical and longitudinal and diagonal parity recording single track error corrections other errors - detectable with recovery means provided	R O O O O		
H20	5.6	Random Access Storage $3.6\ 10^9$ bits minimum Modular Separate elements Removable-transportable	R O O O		
S1	6.2	Operating System Modular-parameterized Controls time-critical operations, interactive modes, and batch processing. Control subordinate basic operating functions for single job execution Upward compatible for multi-programming options	O R R R		
S2		Provide for effective multi-program execution of primary tasks (4-NDPF) (6-OCC) with minimum operator intervention. No hardware halt if any tasks remaining operational instruction messages	R R		
S3		Manage all peripheral units no direct correspondence between devices-	R		
S4		Be able to replace or delete subelements of the operating system; i.e. loader or compiler OCC-dynamically control hardware/software configuration-	R O		
S5	6.3	Loader Load program segments derived from language processors capability to search program library	R		

OCC & NDPF Proposal Evaluation Work Sheet (Continued)

Bidder: _____ Evaluator: _____ Date: _____

Scoring Group Number	Reference RFQ Section	Item	R = Required O = Optional	Comments or Reference Notes	Score
SS1*	6.4	Diagnostic (and maintenance) routines	R	*Diagnostic and maintenance routines are considered as part of support services.	
S6	6.5	File maintenance Delete files Generate files Collate or sort files Move files between devices Edit files Keep file use statistics Provision for file security Provision for file read/write protection	All O		
S7	6.6	Debugging aids For operating system elements and all languages Operate by overlay Employed via operating system Selective controllable dumping Specified symbolically Statement trace capability Postmortem (run) core dumping	 R O O R R		
S8	6.7	Symbolic assembly Produce both absolute and relocatable code. Variable field definition Cross referencing symbol tables Nested macro capability	R R R R		
S9	6.8	Fortran compiler Similar to GSFC F IV Compiler Re-entrant Handle timeshare and multi-programming modes efficient as to code generated and core occupied by generated code. Operate-interactive for time-share and batch mode with efficient compilation for production programs Include extensive diagnostic and debugging aids.	R O O O		
S10	6.9	Other high level translator provides macro language for data manipulation in addition to arithmetic operation- Two modes-conversational-(timeshare) with syntatic error detection ability to modify program at statement level. Batch mode-generate efficient production program code, Control as to mode, selection of outputs and math precision. Standard library routines in compiler language including conversion routines have extensive diagnostic and debug aids.	O		
H21	7.1	Estimates for primary power, In KVA for maximum expanded (208-220/440, 3 phase, 60 cycle ±1, ±5% voltage variation available) Include grounding design features Include cabling for computer equipments (TRW to provide cabling lengths)	O		
	7.2	Mechanical- Physical installation plan Unit dimensions and weights High commercial standards for workmanship and parts	All O		
	7.3	Environment- Operate in 65-86°F temp 20-80 relative humidity Should specify cooling requirements and facilities-raised floor, ducting, etc.			

*Capable of being used by an object program during execution

A

OCC & NDPF Proposal Evaluation Work Sheet (Continued)

Bidder:_____ Evaluator:_____ Date:_____

Scoring Group Number	Reference RFQ Section	Item	R = Required O = Optional	Comments or Reference Notes	Score
H22	8, 1	MTBF - for computer and peripherals based on actual experience with supporting data or if above not available - detail analytical methods used.	O		
SS2	8, 2	MTTR Time required to isolate and replace faulty component based on field experience	R		
		GSFC Service call response time	R		
		Number and years experience of maintenance, Personnel in GSFC area,	R		
		Dollar value of spare parts in GSFC area,	R		
SS3	9, 1	Hardware documentation - 6 sets including - theory of operations, functional block diagrams, logic - equations & diagrams, system timing charts, other educational materials.	R		
		2 sets prior to or with delivery - "as built" - Schematic diagrams Wire lists Component & parts location diagrams for systems units Diagrams and parts lists for each modular subassembly.	R		
SS4	9, 2	Software documentation	R		
		Deliver within 1 month - 12 copies: Computer reference manual Programmer manuals Operating system references manual Assembler reference manual Fortran reference manual Other manuals as related to Software supplied	All R		
		3 copies - (delivery time not given) of: Programming maintenance manuals which provide system program's characteristics.			
		3 reproducible copies - (delivery time not given) of: All program flow charts Annotated program listings			
SS5		Have a group of related support programmers available for correspondence with users and to fix software problems.	R		
SS6	9, 3	System Training - at GSFC, "User" course - 15 people for 6 weeks	R		
		"Systems Programming" 4 people sufficient to enable corrections or mods to operating system,	R		
		"Computer operator" 8 people, starting prior to installation at GSFC.	R		
SS7	10, 2	Acceptance Test NOTE: Installation date is one week following delivery of equipment.	R	Do not score. Certify only that the proposal has wording which specifically meets the acceptance test criteria of the RFQ Sections 10, 2 and 10, 3.	
	10, 3	Scheduled Hours for Acceptance Test			

ATTACHMENT B

Management Evaluation

RFQ	Proposal		0-100 Rating	Weighting Factors	Points
IV(C), 1		I. CONTROL DEVICES			
		A. What controls does supplier propose for the following items?			
		1. Manpower		2	
		2. Program Progress		2	
		3. Reports		1	
		4. Changes		1	
IV(A), A. 1, (3) (4)		II. MANAGEMENT & SPECIALIZED SKILLS - AVAILABILITY & CAPABILITY			
IV(C)		A. Does proposal identify assignment of key personnel by name?			
		1. Available from present complement		2	
		2. Are these people committed to this program		5	
		B. Is Bidder's 1st and 2nd level management qualified in relation to this job?			
		1. Experience		2	
		2. Education		2	
		3. Progression		2	

Management Evaluation (Continued)

RFQ	Proposal		0-100 Rating	Weighting Factors	Points
		C. Does Bidder have the specialized personnel that he required for this job? (Systems Engineering, Programming, etc.)			
		1. Experience		3	
		2. Education		2	
		3. Progression		2	
IV(A), A. 1, (6) IV(C)		III. MANAGEMENT APPROACH & ORGANIZING ABILITY			
		A. Integration of Activities			
		1. Systems Integration Coordination		5	
		2. Design - Standard Items Proposed		10	
		a) Modification of Standard Hardware Excessive re-design		5	
		B. Communications			
		1. Dissemination of Information		2	
		2. Significant Incident Reporting		3	
		3. Problem Solving - methods		3	
		4. Customer Coordination		3	
		5. Subcontractor Information		2	
		6. Timely Advice & Notification of Decisions		3	

Management Evaluation (Continued)

RFQ	Proposal		0-100 Rating	Weighting Factors	Points
IV(A), A. 1, IV(C)		C. Management Philosophy			
		1. Establish suitable sensors as an accurate measure of accomplishments		2	
		2. Flexibility - can Contractor change as required by Customer and program?		3	
		IV. COMMENTS			

Experience Evaluation

RFQ	Proposal		0-100 Rating	Weighting Factors	Points
IV(C), 2, b		I. PRIOR EXPERIENCE ON SIMILAR PROJECTS			
		A. Comparative Experience - (Consider the following:)			
		1. What companies or Government Contracts		3	
		2. Magnitude & Scope		5	
		3. Dollar Value		3	
		II. PERFORMANCE			
		A. History			
		1. Evidence of satisfactory completion of tasks assigned			
		a) Quality		2	
		b) Schedule		2	
		2. Progression of State of the Art and Accomplishment		1	
		3. Problem Solving Capability		3	
		4. Contract Administration		2	
		5. Public Relations		2	
		III. COMMENTS			

Planning and Price Evaluation (To be prepared for each computer proposed, i.e., Lots A, B, C, D, E)

RFQ	Proposal		0-100 Rating	Weighting Factors	Points
Cover Ltr.		I. SCHEDULES			
IV(C)		A. Is Schedule detailed by phase plan for the entire project in accordance with program requirements? (Consider the following factors.)			
		1. Implementation of Plan		2	
		2. Periodic Check Points		2	
		3. Flow Charts		2	
		4. Place of Performance (Geographical Problems)		2	
		II. ABILITY TO RECOVER FROM SLIPPAGES			
		A. Management Flexibility to revise programming to make up for schedule slippage.		4	
		III. PRICE			
		1. Standard Catalog Items Quoted		3	
		2. Quantity Discounts Offered		5	
		3. OEM Discounts Offered		5	
		4. DD 633 Forms Submitted on Modified or Non-Catalog Items		3	
		5. Spread Sheet Adequately Prepared		2	
		6. Spare Parts Recommended		3	

Contract Evaluation

RFQ	Proposal		0-100 Rating	Weighting Factors	Points
I, 14		I. ACCEPTANCE OF TRW TERMS AND CONDITIONS			
		A. Has Contractor taken exception to special clauses, alterations of Contract requirements?		10	
		1. Are exceptions of such magnitude as to complicate negotiations? List exceptions:			
		EXCEPTIONS | DISPOSITION			
I, 15		II. SUBCONTRACTS REQUIREMENTS AND CRITERIA			
		A. Is percentage of Subcontract proposed by Supplier excessive?		1	
		B. How will Supplier control Subcontractors in the following areas?			
		1. Expediting		1	
		2. Planning		1	

Final Business Management/Price Evaluation

RFQ	Proposal		0-100 Rating	Weighting Factors	Points
		I. MANAGEMENT EVALUATION		20	
		II. EXPERIENCE EVALUATION		15	
		III. PLANNING & PRICE EVALUATION		45	
		IV. CONTRACT EVALUATION		20	