

EA/Assistant Director for Engineering and  
Development

MAR 23 1966

CA/Assistant Director for Flight Crew Operations

In reply refer to:  
CF33-64-36

Simulation of spacecraft guidance computer in the Command Module and Lunar Excursion Module mission simulations.

Simulation of the guidance computer has been a major problem in the development of the mission simulators and maintenance of a suitable simulation promises to be a major constraint on launch flexibility. The technique selected by the subcontractor for the mission simulators is a functional simulation - a simulation that will probably require considerable modification effort each mission. Conservative estimates of this update are 3 to 4 months after receipt of data. Since 6 months is the desired training period, this type of approach to the simulation requires a freeze of the spacecraft and mission approximately 1 year prior to flight.

Various other techniques have been under study by Flight Crew Support Division, Apollo Spacecraft Program Office, Computation and Analysis Division, and Guidance and Control Division. These studies have led to the preparation of a work statement for the generation of computer programs which would convert the spacecraft guidance computer program into a form suitable for the mission simulator computers (DDP-224). A copy of the work statement is enclosed.

The problem and the work statement have been informally discussed with Dr. Battan and Dr. H. Lanning of MIT, and Dr. Lanning has expressed particular interest in attempting to develop such a program through utilization of the "Translator" program.

The work statement has also been discussed with the Computation and Analysis Division, and at the request of Flight Crew Support Division, Mr. James Raney has been performing feasibility studies. Mr. Raney has been concentrating on development of a conversion through utilization of an alternate technique referred to as an "interpreter" program. At a joint meeting with Mr. Munty, Mr. Blair-Smith, and Dr. Lanning of MIT, Mr. Raney of Computation and Analysis Division, and personnel of Apollo Spacecraft Program Office, Guidance and Control Division and Flight Crew Support Division, it was the conclusion that

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both techniques have certain merit and appear to be feasible at this time. It was also concluded that there are still many questions that probably cannot be answered until more work is completed. Either technique if totally successful should result in a reduction of over 25% in the lead time on mission freeze. Either technique should also allow late introduction of changes in mission profiles or other similar items that do not materially change crew duties or responses.

Due to the criticality of the problem to the Apollo program, it would be desirable to carry parallel efforts to at least the point where simulator computer hardware configuration commitments are required. Such an approach will allow development of significantly greater confidence in the scheduled availability and functional capability of the end product. It is important that the total effort be initiated immediately and not be postponed until submission of proposals.

To support the requirement it is requested that a OCA be issued to MIT to direct that within 30 days they, under the direction of Dr. Lanning, submit a plan to support all requirements of the work statement. The plan should define detail tasks and milestones, manning and cost data, and the nature of the data and/or support required for the trainer design groups.

It is also requested that the Computation and Analysis Division undertake similar action. It is expected that both efforts shall be continued until one or the other has a clear advantage when compared against schedule and/or computer configuration criteria.

Your immediate action to support and to implement this plan is requested.

ORIGINAL SIGNED BY:  
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Enclosure

cc:  
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Statement of Work  
for  
A Digital Computer Software Package

1.0 SCOPE

This statement of work defines the requirement for the generation of a digital computer software package which will convert an Apollo or LEM spacecraft guidance computer program into a DDP-224 guidance computer simulation program for use in the Apollo and LEM Mission Simulators. .

2.0 DESCRIPTION

The Apollo and LEM Mission Simulators are static simulators which simulate the full Apollo and LEM missions through the solution of systems equations and true motion equations on complexes of DDP-224 computers. (cf. Appendix A)

The guidance computer programs for the Apollo and LEM spacecraft are not available far enough in advance of the mission to allow reprogramming in DDP-224 language for a functional guidance computer simulation in the present configuration of the Apollo and LEM Mission Simulators.

The software package described herein is required in order to rapidly produce a guidance computer simulation in a DDP-224 suitable for use in the Apollo and LEM Mission Simulators. Source data for this package will be tapes containing the spacecraft guidance computer programs.

3.0 PERFORMANCE SPECIFICATION

The following performance specifications constitute the minimum criteria.

3.1 General Requirements

The guidance computer program resulting from the new software package must operate in the computer system graphically illustrated in Appendix A.

3.1.1 The Apollo Mission Simulator computer complex is presently comprised of three DDP-224 computers tied in 8K of common core memory. One of these computers will be made available for the guidance computer simulation, or a fourth computer will be added for this purpose if required.

3.1.2 The LEM Mission Simulator computer complex is presently comprised of two DDP-224 computers tied into 8K of common core and a third DDP-224 will be added for simulation of the guidance computer.

3.1.3 The computer to be used for simulation of the guidance computers within the Apollo and LEM Mission Simulators will be a single DDP-224 for each simulator and the program must not require more than 64K of memory, minus common core.

3.1.4 The supplier shall be responsible for establishing a relationship with the Computer Control Company to secure necessary information on standard DDP-224 options and any additional modifications which may be both feasible and desirable, and make justified recommendations to NASA-MSC as to the exact desired configuration of the DDP-224. Within one month of receipt of the recommendation, NASA will notify the supplier of the configuration which will be made available.

### 3.2 Coordination

It is anticipated that some updates between missions may require an I/O format change, or in some way necessitate some Link reprogramming. This shall be minimized by the supplier, and all such items will be coordinated with Link through NASA, as soon as they become apparent.

### 3.3 Problem Approach

Proposals should include a recommended approach to the problem (translator, compiler, simulator, interpreter, etc.) and a justification for this approach. The supplier shall confirm this approach in each monthly progress report or provide supporting documentation if a change is desired.

### 3.4 Off Line Programs

Any off line programs which are required to be written in the development of the final guidance computer program shall be written for a DDP-224 with magnetic tape, card, or typewriter inputs and magnetic tape, line printer, or card outputs, and will be delivered to NASA-MSO with the final program.

### 3.5 Operational Characteristics

The software program defined by this work statement shall produce a simulation of the Apollo or LEM spacecraft guidance computers with the following characteristics:

- a. The system shall be capable of a complete continuous Apollo or LEM Mission.
- b. The guidance computer simulation is not required to be a bit by bit simulation but shall produce results which are as accurate or more accurate than the same calculation done in the spacecraft guidance computers.
- c. The simulated guidance computer including the digital auto pilot shall operate sufficiently close to real time that both short term and long term effects are perceptibly identical to those in actual guidance computer.
- d. Inputs to the simulated guidance computer from the simulated spacecraft shall be through the common core. Outputs to the simulated spacecraft from the simulated guidance computer shall be through the common core.

Coordination will be required between NASA, Link Division of General Precision, Inc., (the contractor of both the Apollo and LEM Mission Simulators), and the supplier to establish the form of these inputs and outputs. In general the input data to the simulated guidance computer will exist as parallel words representing the spacecraft quantity and will be periodically updated as the subsystem equations in the simulated spacecraft are solved at a fixed rate. The rate for individual equations lies between 20 solutions per second for rapid response systems and 1.25 solutions per second for slow response systems.

- e. Guidance computer functions such as spacecraft hardware checks, etc., which are meaningless in the Apollo and LEM Mission Simulators need not be a part of the simulation.

### 3.6 Configuration Control

The software package described in this work statement shall be capable of producing a satisfactory guidance simulation for spacecraft subsequent to the initial design configuration with a maximum updating manpower expenditure of one man month and within a 1 month time period.

The requirement is based on the following criteria:

- a. A 40 percent change in spacecraft guidance computer programs.
- b. No hardware changes.

The system shall make a sufficiently efficient program conversion such that the single DDP-224 would be adequate for guidance computer simulation if the spacecraft guidance computer programs were expanded to full capability of the present spacecraft guidance computer.

### 3.7 Deliverable Items

The supplier shall deliver the following items:

- a. Software which will make the spacecraft guidance computer program conversion for the:
  - (1) Apollo Guidance Computer to Apollo Simulated Guidance Computer.
  - (2) LEM Guidance Computer to LEM Simulated Guidance Computer.
- b. Any off line programs which are required in the development of the final program.
- c. All documents as described in Documentation Requirements, paragraph 3.8.
- d. All modifications to the initial delivery program.

### 3.8 Documentation Requirements

#### 3.8.1 Computer Configuration Recommendation

This recommendations will be made as specified in paragraph 3.2.

#### 3.8.2 Monthly Progress Report

The supplier shall furnish a monthly report including:

- a. Problems and progress since the last report.
- b. Plans for the upcoming month.
- c. Cost to date.
- d. Projected Cost.
- e. Schedule information.
- f. Items effecting Link Programming.
- g. Any flow charts, descriptions, program listings, etc., which may be available.

This report shall be supplied to NASA-MSC within ten days after the end of the month.

### 3.8.3 Final Documentation

The supplier shall furnish NASA-MSC with flow charts, program listings, major mode flows, etc., and a detailed description of the software package. This documentation shall be supplied within 30 days after acceptance of the software package.

### 3.8.4 Update Documentation

- a. The supplier will provide NASA with all necessary flow charts, descriptions, etc. for any changes to the initial delivery configuration of the software package.
- b. The supplier will provide NASA with a special report on all items affecting common core or in any way requiring Link reprogramming, including a justification or change, as soon as such items become apparent.
- c. At the conclusion of each update, the supplier shall furnish NASA with a brief report concerning the number and extent of changes which were not handled automatically by the software.

## 4.0 TEST AND ACCEPTANCE

It shall be the responsibility of the supplier to conduct all debugging verification, and testing of his programs, prior to final test and acceptance in the operational simulators, on any suitable computers which can be rented or leased by the supplier.

- 4.1 It is possible that computer time can be made available on simulator computers to partially or completely satisfy the requirement for computer time. The desirability of use for testing of a 224 in the proper configuration is recognized and it is possible that such a machine will be available at a later date. Every effort will be made to provide this computer, however, the development of this program must not depend on the availability of this machine.



4.2 Final testing and acceptance shall be conducted on the operational Apollo and LEM Mission Simulators at the Manned Spacecraft Center in Houston, Texas. It is not possible at this time to make a firm commitment of simulator time which will be available for test and acceptance. Estimates should be made based on the following worst case schedule:

- a. Six hours per day availability of the simulators (1 AM to 7 AM)
- b. Simulator operations personnel to be provided by NASA-MSC.
- c. Starting date to be anywhere within the time period of:  
LMS - December 1, 1966 and March 1, 1967  
AMS - January 1, 1967 and April 1, 1967
- d. Simultaneous checkout of the programs in the Apollo and LEM Mission Simulators.
- e. Test and checkout in the operational Apollo or LEM Mission Simulators to be completed within 30 calendar days after the start of testing.

Due to the uncertainty of both computer and simulator availability for testing, it is requested that a detailed cost breakdown of the test and acceptance portion of this development be included.

## 5.0 FIELD SUPPORT

There will be Apollo and LEM Mission Simulators located at the Manned Spacecraft Center in Houston, Texas, and at the Eastern Test Range in Florida. These simulators must all be maintained in the latest spacecraft configuration which could change as frequently as every two months.

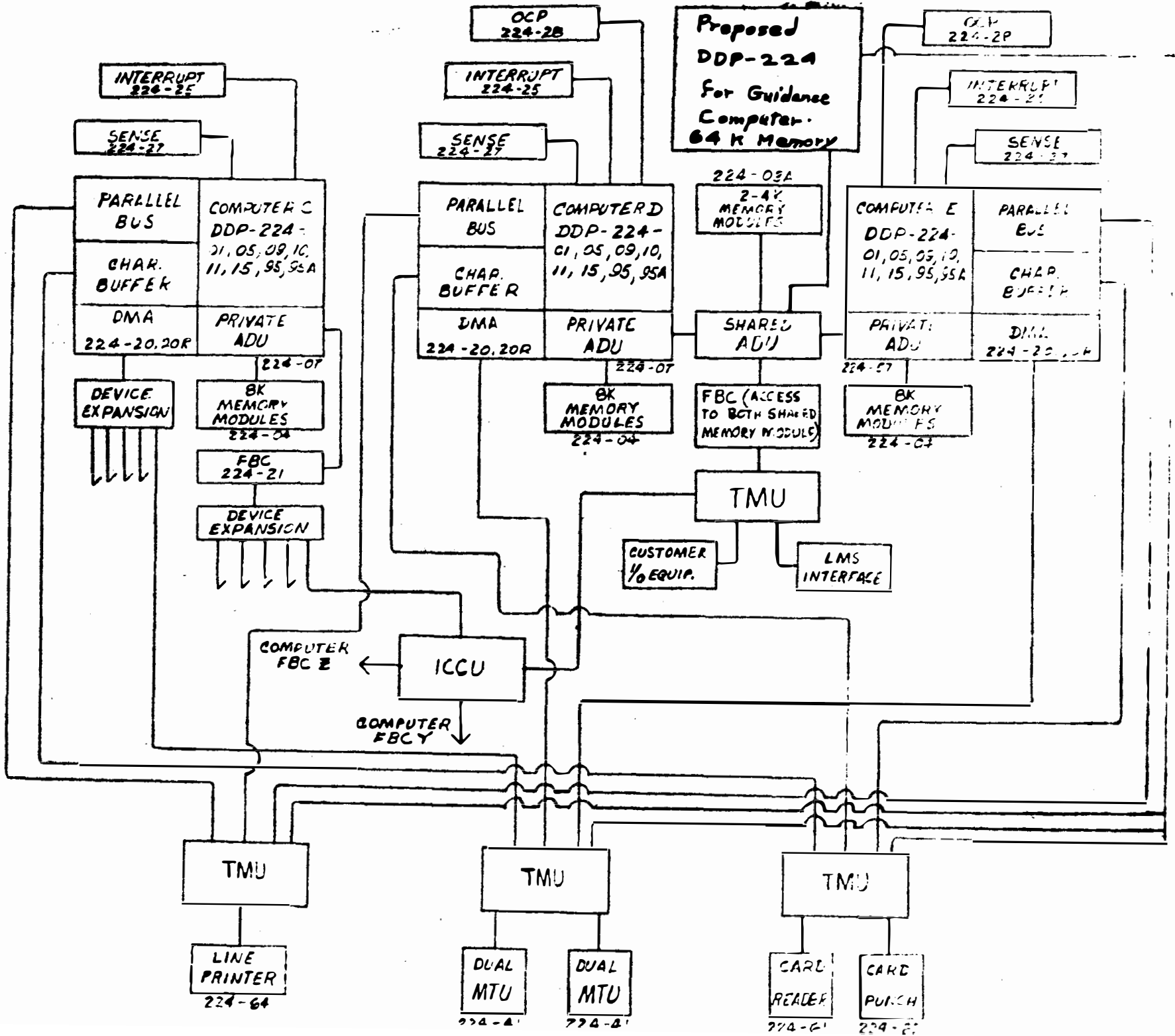
5.1 The supplier shall be prepared to provide sufficient field support at the Manned Spacecraft Center in Houston, Texas, to keep the LEM and Apollo Guidance Computer Simulations in the LMS and AMS

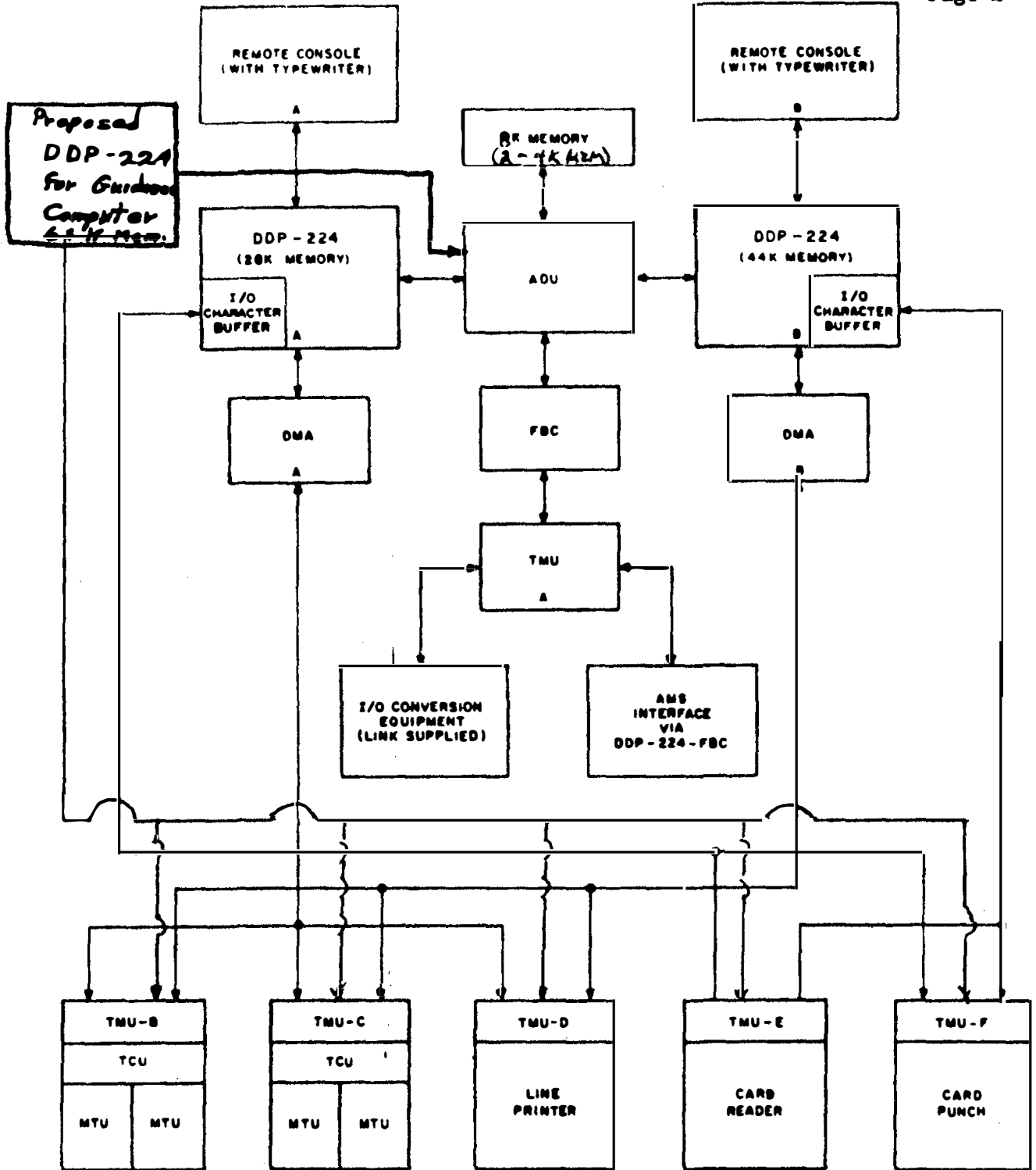
up to the latest spacecraft configuration. These personnel should also be available for travel to the Eastern Test Range in Florida, when required for the checkout of the Guidance Computer Simulations in the ETR AMS and LMS. The ETR and Houston simulators will be maintained essentially identical so the major portion of the work can be done in Houston.

5.2 Estimates should be based on a receipt of MIT tapes two months prior to a required operational date. Four hours per day during the final 2 weeks of this 2 month period would be available for checkout on the operational simulator. No spacecraft hardware changes need to be considered. A 40 percent Guidance Computer software change between mission 1 and mission 2, a 30 percent software change between mission 2 and 3 and a 20 percent change in software from mission to mission for a period of two years should be considered as the required updating task.

#### 6.0 BACKUP

Due to the complexity of the task, not all problems can be anticipated. The supplier, therefore, must be prepared to provide a functional simulation of the guidance computer for the LMS and the AMS, and update this functional simulation in accordance with applicable portion of paragraphs 3.0 through 5.0.





LMS Computer Complex, Block Diagram