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AFHRL-TR-74-108(III)

AIR FORCE

HUMAN RESOURCES

AD B005519

COMBAT-READY CREW PERFORMANCE MEASUREMENT SYSTEM:
PHASE II MEASUREMENT SYSTEM REQUIREMENTS

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December 1974

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NOTICE

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This technical report has been reviewed and is approved.

WILLIAM V. HAGIN, Technical Director
Flying Training Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

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Research for the improvement of combat-crew training, and the sufficient execution of current training programs, are heavily dependent upon good sources of information about trainee performance during and at the end of training. In an effort to improve training performance information, this study is directed to (1) systematic definition of performance and (2) development of methods for measurement.

The current Phase II Report deals with the *requirements for a measurement system* to process the measurement which has been dictated by the previous reports. The following topics are included in this paper: (1) *Research procedures* to indicate the operation in which a measurement system is to serve as a tool in achieving

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research goals; (2) *Measurement processing* to investigate the nature of data processing associated with training research measurement; (3) *System criteria* to guide design tradeoffs; (4) *Preliminary system analyses* to establish measurement system requirements which follow rather directly from the system criteria.

PREFACE

This interim report was produced as a result of the Phase II activities of Contract F41609-71-C-0008, entitled "Research on Operational Combat-Ready Proficiency Measurement." This contract was performed by Manned Systems Sciences, Inc., Northridge, California, for the Flying Training Division, Air Force Human Resources Laboratory (AFSC), Williams AFB, Arizona. Major J. Fitzgerald, Chief, Combat-Crew Training Branch, was the contract monitor. The first phase occupied three months of an 11-month, three-phase study; Phase I was completed on 31 March 1971.

This report is one of a series of seven reports constituting the Final Report of Contract F41609-71-C-0008. These reports are listed below:

Combat-Ready Crew Performance Measurement System:

AFHRL-TR-74-108(I): Final Report

AFHRL-TR-74-108(II): Phase I. Measurement Requirements

AFHRL-TR-74-108(III): Phase II. Measurement System Requirements

AFHRL-TR-74-108(IV): Phase IIIA. Crew Performance Measurement

AFHRL-TR-74-108(V): Phase IIIB. Aerial Combat Maneuvers Measurement

AFHRL-TR-74-108(VI): Phase IIIC. Design Studies

AFHRL-TR-74-108(VII): Phase IIID. Specifications and Implementation Plan

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I. INTRODUCTION

Research for the improvement of combat-crew training, and the efficient execution of current training programs, are heavily dependent upon good sources of information about trainee performance during and at the end of training. In an effort to improve training performance information, this study is directed to (1) systematic definition of performance and (2) development of methods for measurement.

This program is divided into four phases; however, the third phase has been divided further into four parts as the result of expansion of the scope of the program. The structure of the program may be most easily comprehended if the following planned sequence is borne in mind: (1) establishment of measurement requirements, (2) establishment of measurement system requirements, (3) conduct of design studies, (4) development of specifications and an implementation plan, and (5) preparation of the Final Report.

As shown in Figure 1, seven reports will be prepared under this contract; the first three reports prepared all present measurement requirements (Phase I: Pilot Measurement Requirements; Phase IIIA: Combat-Crew Measurement Requirements; Phase IIIB: Air Combat Measurement Requirements), i.e., the measurement to provide information needed for combat-crew training research. These requirements have been determined through surveys conducted at combat-crew training sites. The sites visited are indicated in Table 1.

The current Phase II Report deals with the requirements for a measurement system to process the measurement which has been dictated by the previous reports. The following topics are included in this paper:

1. Research procedures to indicate operation in which a measurement system is to serve as a tool in achieving research goals;

2. Measurement processing to investigate the nature of data processing associated with training research measurement;

3. System criteria to guide design tradeoffs;

4. Preliminary system analyses to establish measurement system requirements which follow rather directly from the system criteria.

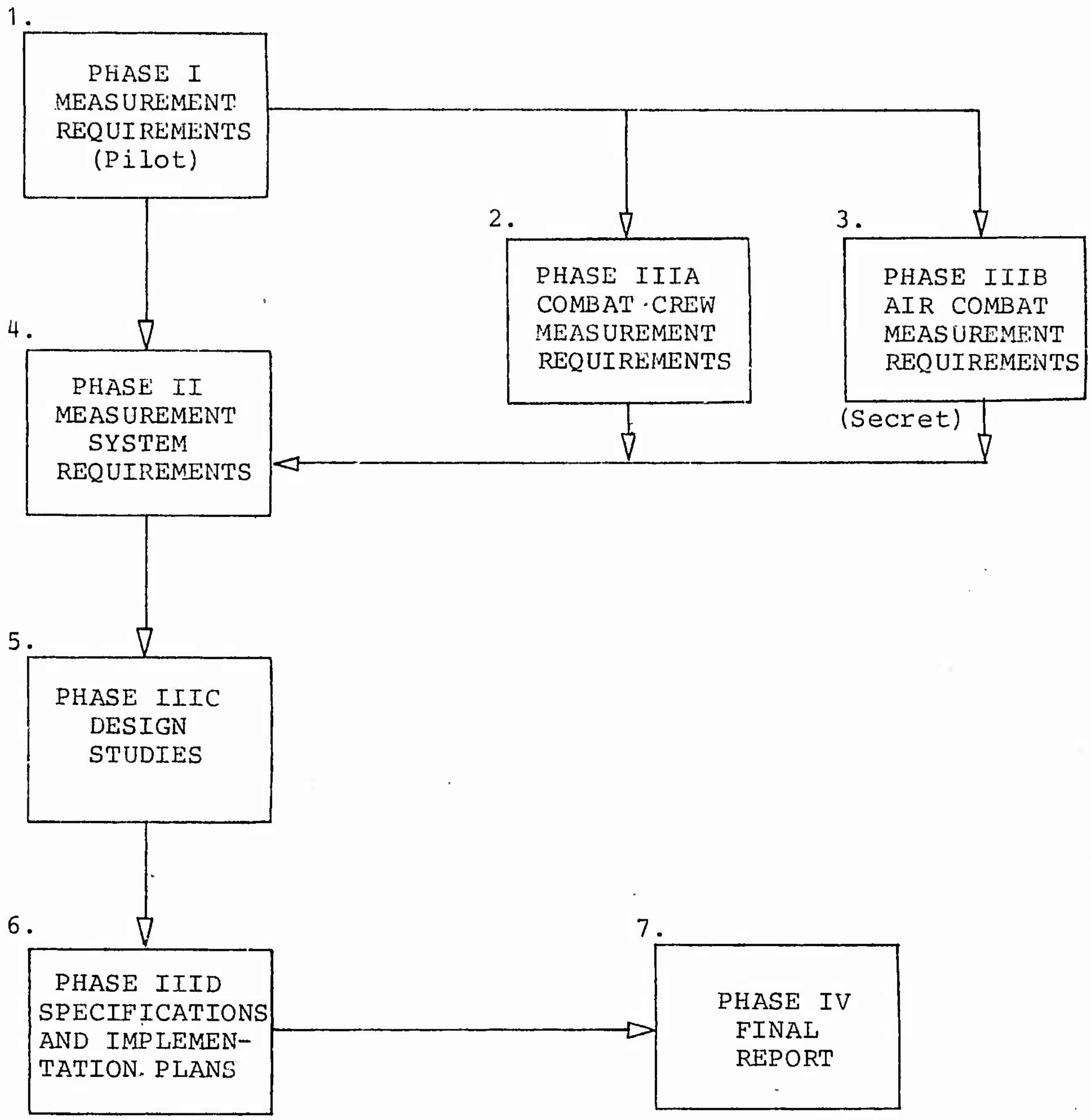

Figure 1. Program Reports.

TABLE 1

COMBAT-CREW TRAINING SITES VISITED TO DETERMINE MEASUREMENT REQUIREMENTS

Topic	Site
A-7	Luke AFB
F-4	Davis-Monthan AFB
F-106	Tyndall AFB
B-52	Castle AFB
C-141	Altus AFB
C-130	Dyess AFB
F-4E Crew	George AFB
C-141 Crew	Norton AFB
Air Combat	Nellis AFB

II. RESEARCH PROCEDURES

The topic of performance measurement is best not considered in isolation, as the activities associated with measurement are integrated into all the major activities in conducting combat-crew training research. In this context, performance measurement exists only to achieve specific research goals. A thorough investigation of performance measurement system requirements, then, must consider the characteristics of such a system in achieving the desired research goals.

A typical research sequence is shown in Figure 2, starting with identification of a research problem and terminating with a technical report. When considering assessment of all factors affecting measurement system design, such as personnel, facilities, equipment and procedures, a meaningful discussion must at least consider the following activities: (1) test plan and measurement specification, (2) data collection, (3) data processing, (4) data analysis, and (5) the technical report.

Test Plan. The test plan and measurement specification is an initial statement of the activities of the research crew in achieving specific data in answer to the research problems posed. All of the specific activities shown at the right-hand side of Figure 2 should be considered in this statement. It is important to note that the measurement system is treated here as a tool for research scientists to use as they proceed through the planned steps in accomplishing a study; it is perhaps more common to consider the individuals of such an activity as supporting the measurement system, but this is a highly nonproductive approach.

Data Collection. Research data must be meaningful and consistent (valid and reliable). For the data collected to lead to meaningful measurement, the research crew must be very familiar with expected performance and the difficulties which will be met in achieving criteria performance; that is, they must be as knowledgable in the task requirements as the combat crews. This knowledge must then be translated into performance measurement to produce meaningful quantification of combat-crew performance. Consequently, it is desired to guarantee that the research crew is entirely aware of the nature of the training mission as planned and accomplished, and all factors related to performance on each flight.

Much information related to performance measurement can be derived from the mission briefing, monitoring the mission (e.g., monitor communications), and the mission debriefing. In some cases there is so much information related to desired performance, mission sequence, surrounding circumstances, and unexpected difficulties, that it may be necessary to make audio recordings for later transcription.

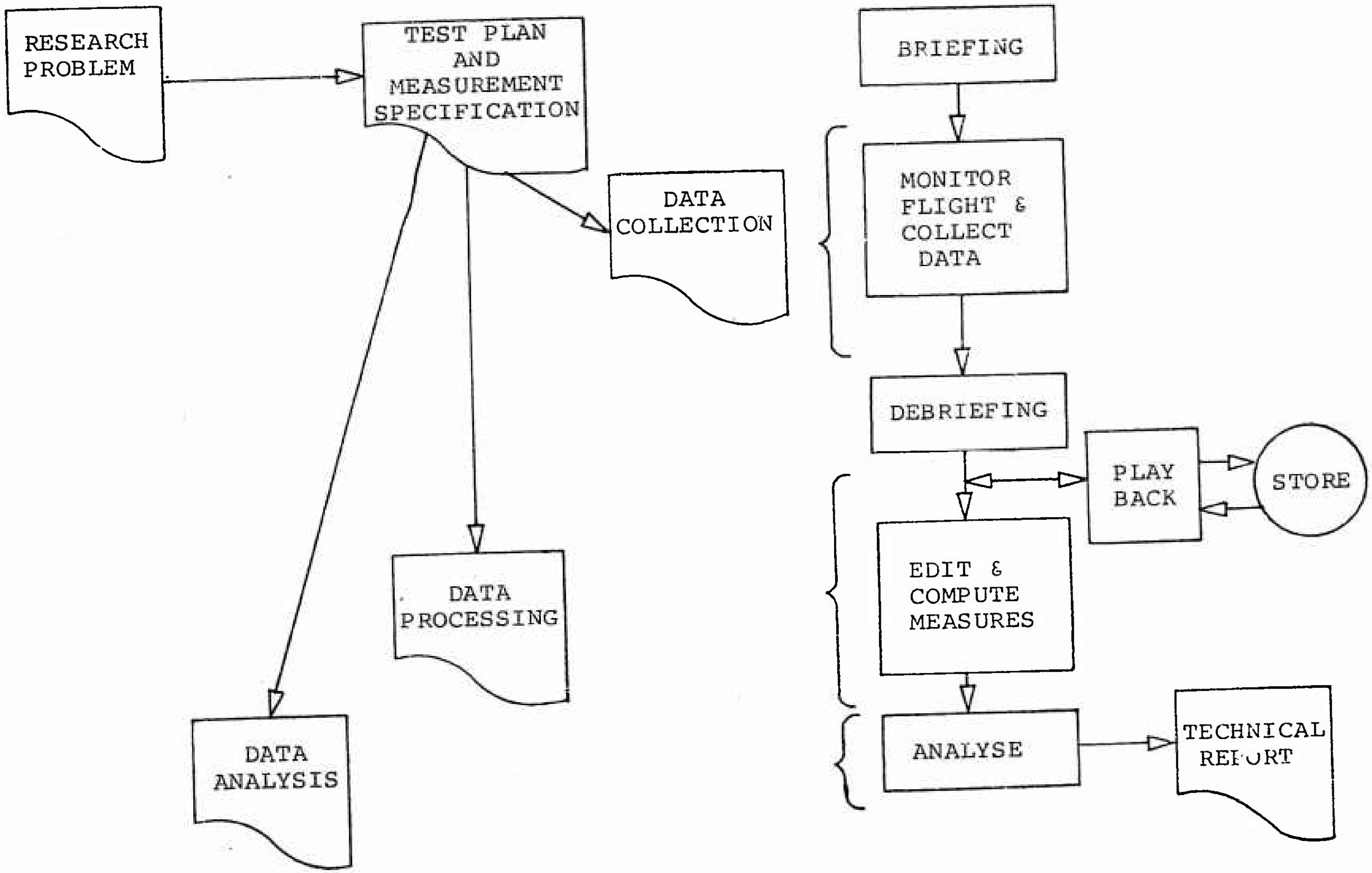

Figure 2. Research Information Processing.

Data Processing. Unless very similar research has been conducted often before, research data processing is an iterative process. The data must be collected and inspected to see if the planned measurement is appropriate and whether more meaningful measurement forms are possible. Alternative measurement schemes may be tried out with some of the initial data collected to pick the best forms. This implies that the raw data are stored in some form which permits convenient re-analysis.

Unfortunately, most data collection systems permit frequent errors. Bad data points are common. Data are recorded in the wrong sequence and are mis-labeled, or require identification for later automatic retrieval. While it is possible to provide much digital computer support to relieve data editing chores, data review and data correction are ultimately tasks to be performed on a case-by-case basis by the research crew in a relatively manual fashion.

Data Analysis. While some statistical treatments of experimental data are relatively standard, data analysis is often a search for the best format to fully present the experimental results. Like measurement development, data analysis is an iterative procedure. The research crew must perform trial analyses with early data collections to test the planned analytical tools (e. g., analysis of variance, multiple range tests, multiple regression, tabulations, plots). As a result of trial analyses, the analytical tools may be changed, or, if unexpected results are noted, even the basic study may be altered.

Technical Report. The goal in creating a research facility is to provide an environment, facilities, procedures and responsibilities to allow the personnel to act in a closed-loop fashion to optimize information outputed from the process. If they are oriented to collecting specific data and publishing these in an open-loop fashion, the results will not be as desirable if the research output is directly related to answering specific research questions. In general, the study group will tend to be properly oriented and professionally associated with their work output if they are responsible for a technical report.

III. MEASUREMENT PROCESSING

The major operations in data processing and analysis, aside from those involved in the direct data collection effort, are shown in Figure 3 and expanded in Figure 4. The major operations are discussed in the following paragraphs.

Data acquisition and data control. Acquisition of data requires some form of data sampling such as data transmission and recording. As data control may involve the training personnel, it should be kept simple; however, this may necessarily include such operations as turning equipment on and off, setting equipment modes, and possibly marking specific events for measurement.

Data edit. The raw data should be stored for convenient playback; each data block must be distinctly identified to indicate personnel, equipment, mission and training conditions. It is likely that data will be obtained from separate sources, requiring that the data be merged and synchronized; for example, data could be recorded inflight, recorded from ground-based equipment, and collected from instructors in the form of subjective judgments.

Training interface. In addition to providing research information, the collection of performance data is a valuable source of information to the instructor to improve training, if such information can be presented in a readily usable form for training debriefings. Further, participation of instructors in the measurement process is often desirable. Review of computed measures with the instructors, in comparison with the performance as they interpret it, can be a valuable stimulus to improved measurement development. Post-mission event marking may be critical to achieving some forms of performance measurement. Subjective judgments may be collected for correlation with other measurement. However, these benefits are only likely to occur if there is a method for presenting a summary of a given flight so that specific events in that flight can be marked and discussed. Whereas data may be encoded in some form convenient for research processing, the preceding requirements indicate collection, or collection/conversion, in a form analogous to the aircraft cockpit presentation so that performance may be viewed in a form readily interpreted by flying personnel as well as research personnel.

Measurement calculations. The measurement calculations chosen of course will depend on the information desired and the specific procedures developed for measurement. To calculate a given measure, other parameters may be needed in addition to the primary performance parameters (such as air speed or heading) to perform the calculation (e.g., weight off the wheels to indicate the parameters at lift-off) and to compare to desired or command performance. These parameters must also be entered into the

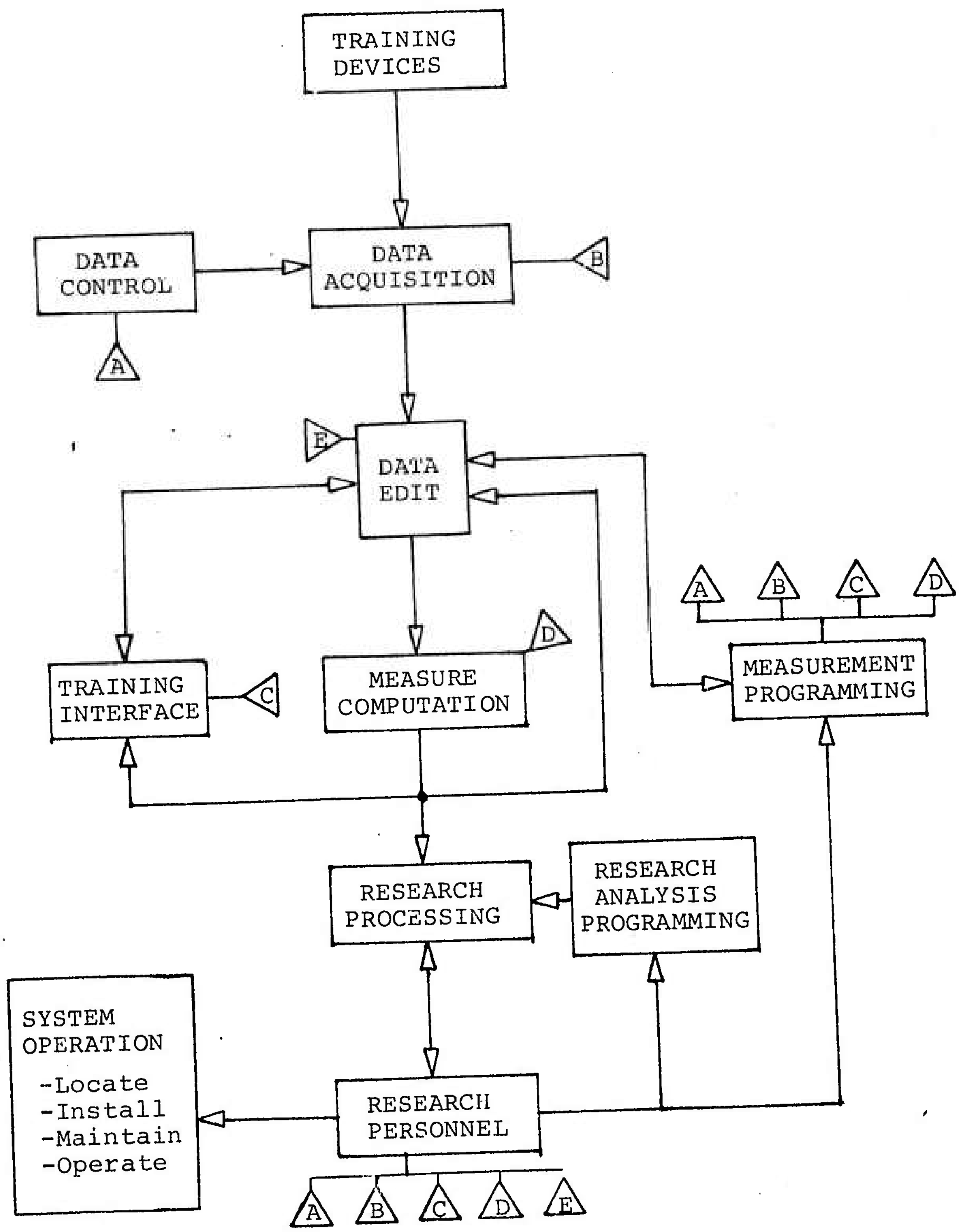

Figure 3. Measurement System Block Diagram.

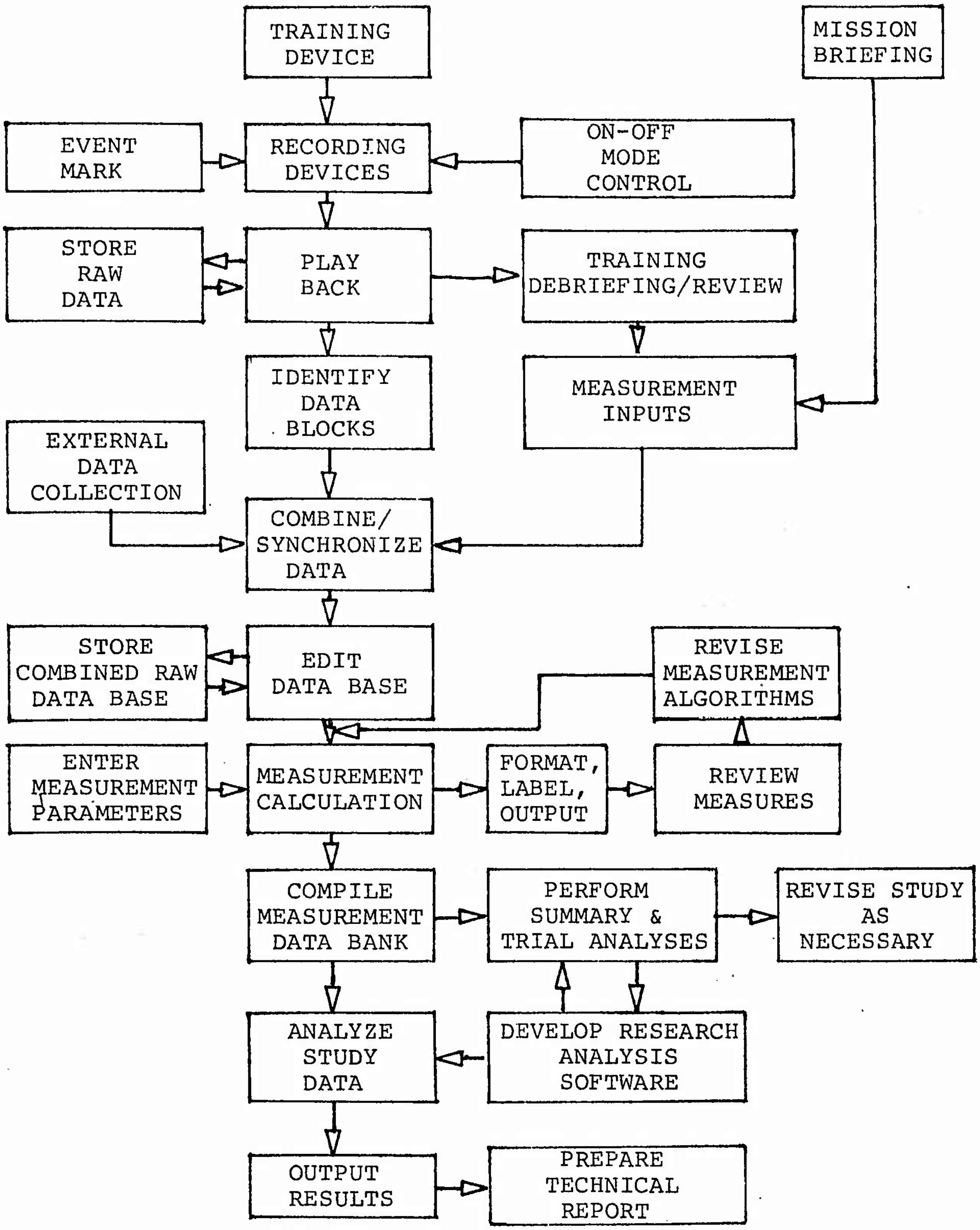

Figure 4. Research Measurement Processing.

system as required for the type of maneuver under analysis. The calculated measures form a secondary data base; that is, a data bank is gradually accumulated during a study upon which various analyses may be performed. This data bank requires care and maintenance much like the raw data base, and additional attention to create a file structure for automatic information retrieval.

Review of the computed measures is likely to reveal inadequacies unless the measurement has been previously thoroughly tested. Often incorrect assumptions are made (perhaps unknowingly) in the design of measurement; or, the performance measured is not precisely that desired. It is therefore extremely important to the design of valid and reliable measurement (and therefore to the success of the entire research effort) that the opportunity and capability for trial-and-error measurement development be permitted. Unfortunately, while much measurement development can take place prior to testing, many kinds of measurement problems do not appear until tested with operational data.

Measurement and Research Analysis programming. It may be seen from Figure 3 that the measurement programming and research analysis programming operations are key links between the research personnel and the tools with which they are attempting to achieve the research goals. This link must be kept as simple and as direct as possible. It is therefore desirable that the research personnel be capable of performing most of the programming themselves, although the need for an experienced systems programmer may also be justified.

Since combat-crew training research studies are such rich sources of information, data processing and analysis generally entail operations with large volumes of data. A digital computer is a modern necessity for this purpose. For the types of operations necessary for research, the digital computer is only useful as a tool if the research crew is capable of the preparation of computer programs for data processing and analysis; further, they must have access to a computer on an extensive interactive basis. BASIC, ALGOL, and FORTRAN are languages which permit scientific personnel to directly communicate with a digital computer; for the current purposes, the FORTRAN IV language provides commonality to other research and utility programs, ease of use, and power for scientific computation.

Research processing. As previously discussed, selection of the proper research data treatment also requires an iterative approach similar to that recommended for measurement development. Consequently, the same comments about availability of the digital computer and programming language apply.

System operation. From the foregoing, it can be concluded that the research team should consist of research scientists with military flying knowledge and programming skills in addition to other requirements for performing empirical research.

Programmers may be required depending on the computational complexities and the size of the data processing facility. Engineers and technicians will be needed to install, repair, and maintain any equipment. Additionally, since such data processing inevitably involves many manual operations, data clerks and secretarial help will be required.

Combat-crew training research may take place at any of a large number of Air Force bases. There is also a distinct possibility that each study undertaken may occur at a different place. The research facilities at most training bases are rather meager; consequently, the facilities must be collected, installed, maintained, repaired, and operated at each site as needed. The ability to locate and maintain all required ingredients is necessary to the performance of timely and successful training research.

IV. SYSTEM CRITERIA

System criteria are needed to guide design of an appropriate measurement system and to provide a basis for tradeoff analyses of candidate systems. The criteria generally must be as complex and multidimensional as the system to which they apply; however, if a simple criterion is desired, one should view a measurement system as an information processing system and ask that it be feasible and usable, but most importantly that it provide the information needed for researdh.

Criteria for a measurement system to produce needed information for combat-crew training research are listed in Table 2. Eleven criterion statements are made; each of these is discussed in the following paragraphs.

Provide needed information. During visits to selected combat-crew training units for six different aircraft, information requirements for use during such training were identified. The training information needs were summarized in the form of prototype measurement (these are to be found in Volume II). Prototype measurement formats identify information needed during each maneuver of each training phase, representing each specific measurement as a blank entry after a caption indicating the category of information required. The format thus produced represents a computer printout illustrating the type of measurement needed. These formats are quite useful for the development of measurement; however, they are also a useful checklist for evaluating the completeness of measurement produced by candidate measurement systems. These formats, then, provide a means for determining whether a given system provides needed information.

The prototype measurement will lead to the development of detailed measurement definitions, which may modify the information the measurement system will be expected to produce. Further, specific research may pose special information requirements not found from examination of the operational training needs; and, additional information needs for training may be discovered in the future. Consequently, the statement of information requirements developed in this study must not be used without also considering needs for flexibility and growth potential.

Provide data in a useful form. While the current measurement system design is oriented primarily to the needs of training research, it is conceivable and most desirable that it also be of value for operational combat-crew training. It is desirable that the information produced is readily interpretable by instructor pilots and training managers to (1) provide consultation for the development of better measurement, and (2) allow pilot inputs to the system for measurement not tractable with fully automatic techniques. One may conclude then that information should be

TABLE 2

RESEARCH MEASUREMENT SYSTEM CRITERIA

1. Provide needed information.
2. Provide data in a useful form for (1) combat-crew training, and (2) research objectives.
3. Short research cycle time.
4. Minimum initial/sustaining costs.
5. Minimum data distortion.
6. Compatible with different training devices.
7. Permit iterative design of valid measurement.
8. Minimum interference with training processes.
9. Permit correlation with data from external sources.
10. Minimum space, weight, cooling and power requirements.
11. Effective self-sufficient personnel/facility configuration capable of achieving training research objectives.

presented in a form readily interpreted by pilots, i.e., in a form similar to that encountered while in flight. On the other hand, the research scientist requires his data in a numerical format for editing, maintaining accuracy, and for further computation. For research purposes then information probably is best presented in tabular or plot format. Consequently, both Research Scientist and Instructor Pilot format requirements should be considered during evaluation of alternative candidate measurement systems.

Short research cycle time. The information produced by a measurement system will be fully useful only if it is timely. It must be possible to begin measurement for research soon after a research problem is identified or the results may be too late to affect key decisions. If data collected are to be useful for training debriefing the results must be available shortly after a mission is ended (less than an hour). If the data collected are to be reviewed to determine whether additional data collection is necessary to replace missing or incorrect data, the data must be available for inspection at least on the same day. Data reduction and analysis of the complete data collected during a given study must be available for interpretation within a relatively short period after the last data are collected; otherwise, specific data idiosyncrasies are forgotten and the results are not timely. Since it is expected that combat-crew training research will be required to be executed according to demanding schedules, the ability of a measurement system to respond quickly to research needs is a very important consideration.

Minimum initial/sustaining costs. As research must always be performed with limited budgets, system costs may be the primary evaluation factor. All costs must be considered. Initial costs include modification of devices, installation, design and equipment purchases. Sustaining costs include personnel salaries, facility leases, supplies and services. These costs must be traded off against the utility of the information derived.

Minimum data distortion. Any real information processing system changes the information upon which it operates in undesired ways. In a measurement system, loss of data fidelity leads to invalid, unreliable, or missing data. If data are frequently missing or uninterpretable, research studies can become meaningless.

Compatible with different training devices. Training research may take place with any existing or proposed training devices. As the goal of the research may be to evaluate the effectiveness of a given training device, it will be necessary to collect identical measures for comparison in each training device (including probably operational aircraft). A measurement system for training research will therefore be required to operate in operational aircraft, large flight simulator, and smaller part-task trainers.

Permit iterative design of valid measurement. Measurement design can proceed in a purely analytical vein only to a point. The measurement designs must then be tried out with real data sampling a variety of human behavior and system conditions. The Research Scientist is then provided with data which he can use to design different or better measurement. The measurement system must provide the capability for change in a relatively easy and quick fashion. If such iterations in measurement design are sufficiently convenient, valid measurement appropriate to the research needs may soon evolve; without capability for iterative measurement design, the ability to properly develop measures will be surely impaired.

Minimum interference with training processes. While all measurement in some way affects the process measured, it is a goal of all measurement to minimize such interference. A measurement system for training research should be inconspicuous requiring little or no attention from the student or instructor.

Permit correlation with data from external sources. All research data may not emanate from the same source. For example, some data may be collected inflight, others from ground-based equipment, and still others from instructor judgments, operational publications, or even the data of an independent study. For any given study, data from any number of such data sources may be collected, combined and correlated.

Minimum space, weight, cooling and power requirements. It is probable that a measurement system for combat-crew training research will involve measurement of performance in fighter-type aircraft. In such a circumstance, it is very difficult to place any additional equipment onboard, and it will be more difficult if the equipment is large, heavy, and requires extensive cooling or power resources. In any case, for any application, the ease of use of measurement devices will be enhanced by minimizing demands for physical resources.

Effective self-sufficient personnel/facility configuration. A combination of people and tools is necessary to perform training research. The major tool needed is a performance measurement system. The proper combination of ingredients must all be brought together. All types of people and equipment must be sufficiently near to each other, and not scattered about the country where they cannot effectively interact. The proper mix is also important. A variety of talents, and a mixture of manual and high-speed computer techniques are likely to be most successful.

V. PRELIMINARY SYSTEM ANALYSES

While detailed design studies will be reported later, this section presents a number of preliminary analyses. First, an initial determination of parameters needed for measurement is made; these affect the size and complexity of the data acquisition system needed and allow estimation of the volume of data to be processed. Next, some initial design decisions are made so that later design studies can concentrate on remaining design details: (1) the basic form of the data acquisition system is determined, (2) specific data processing equipment alternatives are listed, and (3) a general personnel/facility configuration is discussed.

Measurement parameters. Even if information requirements are fully specified, the parameters which must be sensed to provide required measurement are not obvious and do not follow directly. Figure 5 may help to clarify the relationship. In the figure, the output measures (0) correspond to the information requirements. All steps in producing each measure must be known before all the parameters which must be sensed can be determined.

In addition to basic test parameters (M), the following types of parameters may be needed: (1) parameters needed for implementing logic to start and stop measurement computations, (2) information related to desired performance, and (3) error information derived from the difference between actual and desired performance. In short, given output measures 0, to determine other parameters which must be sensed (M,S,D,E), it is necessary to determine the logic and computations to be used in measurement (i.e., the measurement algorithms).

While exact determination of all sensed parameters must therefore await full development of measures, candidate measurement algorithms were devised (for later review and expansion). These preliminary algorithms were used to produce the list of measurement parameters presented in Table 3. This list can be used to estimate the magnitude of data acquisition and data processing capability required.

It may be seen that there is a rather large number of parameters to be sensed if one is to design a system capable of measuring for all phases of training. A total of approximately 90 parameters are needed for all phases of combat-crew training based on this initial tabulation. In Table 4 the estimated number of parameters for each training phase is listed along with note of parameters which may pose special instrumentation problems.

These data indicate that a data acquisition system may be required to sense approximately 90 parameters, and record 14-34 parameters during a training mission. With the possible exception of stick movement parameters, which may require

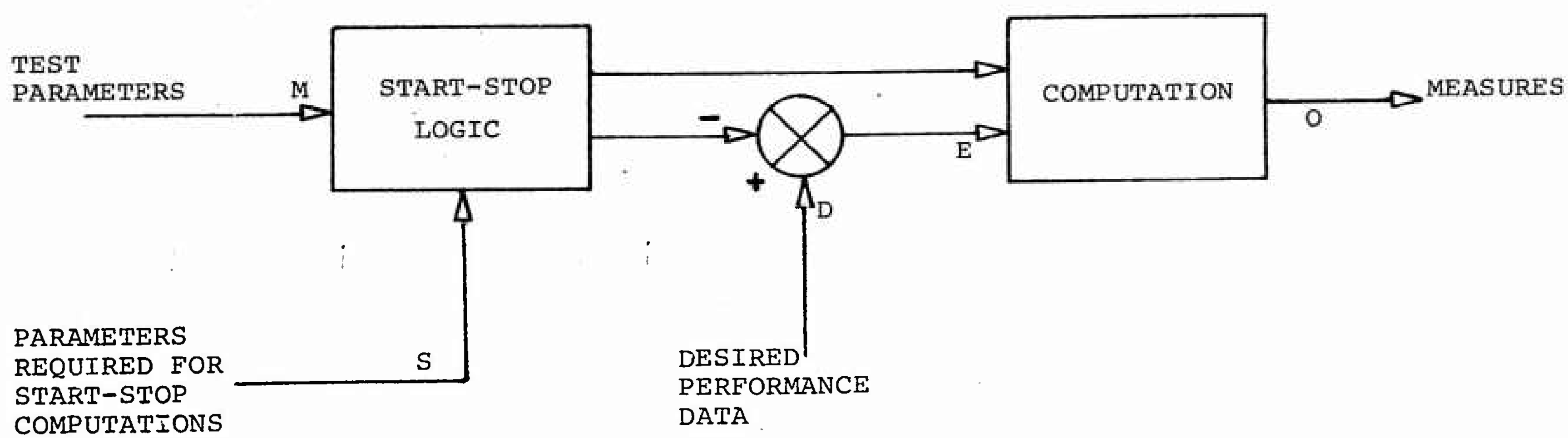

Figure 5. Identification of Measurement Parameters.

TABLE 3. MEASUREMENT PARAMETERS

A. AIRCRAFT CONFIGURATION
1. Stab Trim
2. Flaps
3. Gear Posn.
4. Nose Gear Steer Engage
5. Main Gear Contact
6. Drag Chute Out
7. Speed Brakes Out
8. Spoilers
9. Wheel Brakes On
10. Thrust Reverse
11. Refuel Probe Engage

B. AIRCRAFT PARAMETERS
1.-2. Stick (Pitch & Roll)
3. Pitch
4. Pitch Rate
5. Roll
6. Heading
7. Turn Rate
8. Slip
9. Fuel Quantity
10. Fuel Flow
11. TIT, EPR,...
12. Throttle
13. IAS
14. MACH
15. ALT (MSL/FL)
16. Radar Alt.
17. Vert. Vel.
18. Ang. of Attack
19. G

C. FLIGHT PROFILE ERROR DATA
1. Freq.: VOR
2. : Tacan
3. : UHF
4. : VHF
5. To/From
6. Marker Beacon
7. Glide Slope/Loc.
8. Bearing
9. Radial
10. ARC(DME)
11. ADI Steer Bars
12. *ALT.
13. Fix Error
14. X-Track Dev.
15. Along Track Dist.
16. *Heading Error
17. *Drift Angle
18. *IAS

D. TIME
1. GMT

E. RELATIVE POSN. (OTHER A/C, TGT. OR FIX)
1. Azimuth
2. Elev.
3. Range
4. V_C
5. Aspect Angle
6. Tgt. Heading
7. Tgt. MACH

F. HUD/IR/RADAR/FIRE CONTROL SYS.
1. Aim Pt. Desired
2. Aim Pt.
3. Offset Rng/Brg/Δh
4. Flt. Path Marker
5. Bomb Fall Line
6. Aim Point Error
7. *Error vs. Aim Pt. (FPM)
8. Antenna Elev.
9. Azimuth
10. Range
11. Range Gate
12. V_C
13. ½ Action SW
14. Lock SW
    Lock Mode
15. Doppler Drift
16. Doppler G/S
17. Weapon Rel. SW
18. Weapon Rel.
19. Dry Run Call
    Missile vs. A/C
20. Δ Elev.
21. Δ Azimuth
22. Δ Range
23. Δ V_C

G. GROUND SCORING
1. Impact Pt.
2. *Hits
3. Foul

H. TERRAIN AVOID. RADAR
1. Mode: Plan/Profile
2. Tgt (x)
3. Tgt (y)
4. HRL
5. # Scans

I. TANKER
1. Lights: Up/Down
2. : Fore/Aft
3. Centerline Dev.

*May be computed from other parameters

TABLE 4

APPROXIMATE NUMBER OF MEASUREMENT PARAMETERS FOR EACH FLIGHT PHASE

FLIGHT PHASE	REAL-TIME MEAS. PARAMETERS	SPECIAL INTERFACE NEEDS
T.O., Climb & Level-Off	15	Stab Trim Gear Contact
Pattern, Land & Go-Around	20	Nose Steer. Wheel Brks. Rwy, Dist & C/L
Stand. Inst. Approach	12	
Pen, Tacan Approach	14	Bearing X-Track
ILS Approach	17	Stab Trim
GCA Approach	20	Stab Trim Tacan Freq. X-Track
Formation	13	Stab, Throttle, Stick Position
Intercept	34	Missile/Scope Position
ACM	25	
Air Refueling	16	Stab Trim, Stick Lights, Position
Ground Attack	24	Wpn Rel, Offset, X-Track, Posn, Ground Scoring
Air Drop (Single-Ship)	23	Stick, Throttle, X-Track, Along Trck Position, Wpn Rel.
Air Drop Formation	21	Posn., X-Track, Throttle Rate, Wheel Brakes, Gear Control
Terrain Avoidance	14	Radar, X-Track

sampling 10-20 times per second, parameter sampling should not have to exceed 1-2 times per second.

These data are useful for initial specification of candidate measurement systems for design tradeoff studies.

Basic form of data acquisition. Three basic forms of data acquisition have been considered; these are (1) telemetry, (2) onboard computation, and (3) recording.

Telemetry involves the real-time transmission of measurement parameters from an aircraft to a ground station for processing. The research team is permitted to monitor and closely supervise data acquisition, and to process data prior to return of the aircraft. Therefore, measurement may be calculated for presentation to the flight crew immediately upon their return. A directional tracking antenna may be required, but in any case, reception will be limited to line-of-sight, restricting the range over which data may be collected. Further, real-time data processing of a large volume of data requires a large high-speed computer, and measurement algorithms are restricted if all calculation must proceed as data are acquired.

Measurement results may also be available at the end of a flight if measures are calculated onboard the aircraft during the mission. The direct calculation of measures in a completely automated fashion would greatly simplify the subsequent measurement and analysis processes. A small onboard computer can conceivably accomplish this end, but it would require efficient programming by experienced programmers. Research personnel would have to operate indirectly through these programmers, and the nature of the software would be such that any changes would be very difficult. Consequently, it would be inconvenient to iteratively develop new and improved measurement. It is concluded that, with an onboard computer for measurement, the research personnel would be restricted in scope and flexibility in attempting to achieve research goals.

The remaining data acquisition alternative is recording with subsequent replay for analysis. Recording may take several forms: (1) magnetic tape recording of sensed electrical signals, (2) video tape recording of the outputs of a vidicon camera, and (3) photography. In any case, these recordings must be processed after a flight returns and the recording can be removed from the aircraft. Recording does not suffer from the disadvantages of the other alternatives, however, permitting analyses and re-analysis, not necessarily in real-time, and permits trial-and-error development of measurement.

It is therefore recommended that a form of data recording be used for combat-crew training measurement. Subsequent tradeoff analyses will be conducted among alternative systems all based on data recording. This assumption is not duly restructive, since forms of telemetry or onboard computation may also be used with recording; that is, while recording is the selected primary form of data acquisition, the other forms are not totally excluded from future consideration.

Alternative types of data processing equipment. Four types of data processing facilities are identified in Table 5. Digital computer support may be in the form of a dedicated computer, a time-share computer, or a remote computer. Depending on the form of data recording selected, specialized conversion and playback equipment will be needed.

TABLE 5

DATA PROCESSING FACILITIES

1. Dedicated Computer: TTY, Computer, Card Reader, Line Printer, Mag. Tape Units, Disc.

2. Instrumentation Conversion Equipment.

3. Time-Share Computer.

4. Computer at Remote Location.

Conversion and playback equipment of course are a necessary part of the data acquisition portion of the system. These equipments are mentioned here for completeness as they would reside with data processing equipment. Conversion equipment varies with the form of information coding (frequency modulation, pulse duration modulation, pulse code modulation, etc.); therefore, generalized equipment may be needed if data may be produced with various forms of airborne equipment. Otherwise, the principal tradeoff is between the remaining three forms of digital computer facilities.

Data processing facilities dedicated to flight performance measurement invariably include a small general-purpose digital computer (16-32K memory) with a teletype terminal, card reader, line printer, magnetic tape units, and disc storage. For small operations, the disc storage can be eliminated, but the disc greatly improves capacity and speed of operation.

A time-share computer facility consists of a teletype terminal connected via a telephone network to a large computer complex. It permits use of a large high-speed computer on a pay-as-you-go basis. The teletype is limited in the amount of input and output data which may be processed. It is therefore suitable only where manual data entry is required, such as with video or photographic recording. Nevertheless, large scale analyses may be performed with such a system with high-volume output on fast printers at the computer complex (and mailed to the user).

Both a dedicated computer and a time-share terminal offer a tool which Research Scientists may interact on an essentially unlimited basis. This interaction is vital to measurement development and research analysis. As this level of interaction is not permitted with a remote computer facility, this option must be strongly rejected. One may attempt to collect data, write programs, and then go to a remote computer facility for data reduction, measurement calculation and statistical analyses; however, this approach has never met with much success as a permanent mode of operation.

Personnel/facility configuration. Based on consideration of the design criteria presented in Table 2 and past operational experimental efforts, it is recommended that the personnel/ facility configuration should have the characteristics listed in Table 6. Combat-crew training research will require operation at different training bases on short-notice, implying that all needed facilities are easily established at each new location. If large and complex facilities are determined to be necessary, these should be housed in a transportable enclosure. The digital computer is a basic tool for this type of data processing, but to achieve maximum benefits the research team must have ready exclusive access to the computer and any programmer personnel which may be required. Of course, data conversion and playback equipment appropriate to the type of recording used must also be housed for ready access.

As the measurements collected may also be used directly in the training process, and since measurement review by Instructor Pilots may be necessary in the course of development, an interface (i.e., display or cockpit console) will be needed to display information interpretable by pilots.

The facilities should include standard office space and equipment, facilities for test and repair of measurement and computing equipment, and storage. Aircraft communication equipment will permit monitoring actual events on measurement flights so that the research crew know the circumstances surrounding data collection.

The basic research team consists of Research Scientists, data clerks and secretary, engineers, and technicians. Programmers must be included if the resultant digital computer facility is large, and in the initial stages of establishing the measurement facility. Of course, the number and type of engineers and technicians will depend on the specific equipment ultimately specified in this study. Manual data operations are inevitable in training research, posing a requirement for data clerks. A secretary can also aid in manual data operations as

TABLE 6

PERSONNEL/FACILITY CONFIGURATION

Transportable facility
Direct Access to Digital Computer and Programmer
Training Interface
Research Scientists
Data Clerks and Secretary
Engineer and Technicians
Data Conversion and Playback Equipment
Standard Office Space and Equipment
Test and Repair Facilities
Storage
Aircraft Communications Equipment

well as transcribing audio recordings and preparation of technical reports. Naturally the Research Scientists are the key personnel; they must, at a minimum, possess knowledge and skills in the following areas: (1) training psychology, (2) field research, (3) military flying, (4) statistical analyses, and (5) programming.