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This Final Report summarizes the development of a simple, yet relatively smart electro-optical system has been devised to do real-time monitoring of the optical state of the atmosphere. The system concept has been built around three solid state, no moving parts, transducer assemblies interfaced with a small dedicated microprocessor that can control the system in either a semi-automatic, or an operator interactive mode.

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20. ABSTRACT continued:

The development status at the conclusion of the shortened contract interval is such that; a) each of the system sub-assemblies has been evaluated in an operational mock-up configuration, b) each has performed adequately to indicate technical feasibility, and c) the miniaturized nephelometer and on-board computer systems have been developed and fabricated to the prototype hardware stage.

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AN EXPERIMENTAL DEVICE FOR REAL TIME DETERMINATION OF SLANT PATH ATMOSPHERIC CONTRAST TRANSMITTANCE
(Prototype Status)

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Prepared for

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

SUMMARY

This Final Report, under Contract No. F19628-81-K-0023, summarizes the development status of a simple yet relatively smart electro-optical system that has been devised to do real-time monitoring of the optical state of the atmosphere. The system concept has been built around three solid state, no moving parts, transducer assemblies interfaced with a small dedicated microprocessor that can control the system in either a semi-automatic, or an operator interactive mode.

As discussed in this report's preceding companion report AFGL-TR-82-0125, the development status in March 1982 was such that each of the system sub-assemblies had been evaluated in an operational mock-up configuration and had performed adequately to indicate technical feasibility of the overall design concept.

Due to unforeseen budgetary restrictions, it was necessary to prematurely terminate the development of this prototype device after only sixteen months of the proposed twenty-four month program. As a result, the design and fabrication schedules were revised in late FY82 in an attempt to optimize the achievable end item. The miniaturized nephelometer development received maximum priority for sub-assembly completions. This report reviews the final sub-assembly configurations as completed at contract termination.

The development status at the conclusion of this shortened contract interval is such that; a) each of the system sub-assemblies has been evaluated in an operational mock-up configuration, b) each has performed adequately to indicate technical feasibility, and c) the miniaturized nephelometer and on-board computer systems have been developed and fabricated to the prototype hardware stage.

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LIST OF ILLUSTRATIONS

AN EXPERIMENTAL DEVICE FOR REAL TIME DETERMINATION OF SLANT PATH ATMOSPHERIC CONTRAST TRANSMITTANCE

(Prototype Status)

Richard W. Johnson

1. INTRODUCTION

As noted in the preceding companion report AFGL-TR-82-0125, Johnson (1982), there exists a strong and long-standing need for a small, power efficient device for the measurement of key atmospheric optical properties in a broad variety of activities supporting scenarios in military tactical operations, meteorological reporting and forecasting procedures, and fundamental research into atmospheric influences on image propagation.

The airborne instrument system whose development status is described in the following paragraphs is intended to fulfill this need. It is designed to accomplish this goal by providing measurements and computations related to the optical state of the atmosphere, similar to those described in Duntley, *et al.* (1976), but in a simplified form suitable for on-board microprocessor control and display. The data base and research programs upon which the concept of this instrumentation system has been built were conducted by the Visibility Laboratory in cooperation with, and under the sponsorship of the Air Force Geophysics Laboratory.

A simplified conceptual pictorial illustrating the essential system components is sketched in Fig. 1-1 which has been abstracted from the preceding interim report, Johnson (1982). The airborne system has been developed under a design concept pursuing a low power, solid state, no moving parts philosophy. As illustrated, assemblies one and two provide upper and lower hemisphere radiance distributions. Assembly three provides directional volume scattering coefficient measurements. The entire system is conceived as an airborne unit, adequately miniaturized to be packaged in a small aircraft tip tank, an RPV, or general purpose munitions pod. The general program plan for accomplishing this developmental task is outlined in Fig. 1-2. It should be noted that the program termination occurred during the Prototype Fabrication Stage of the program schedule, and thus this report will not contain test and evaluation data.

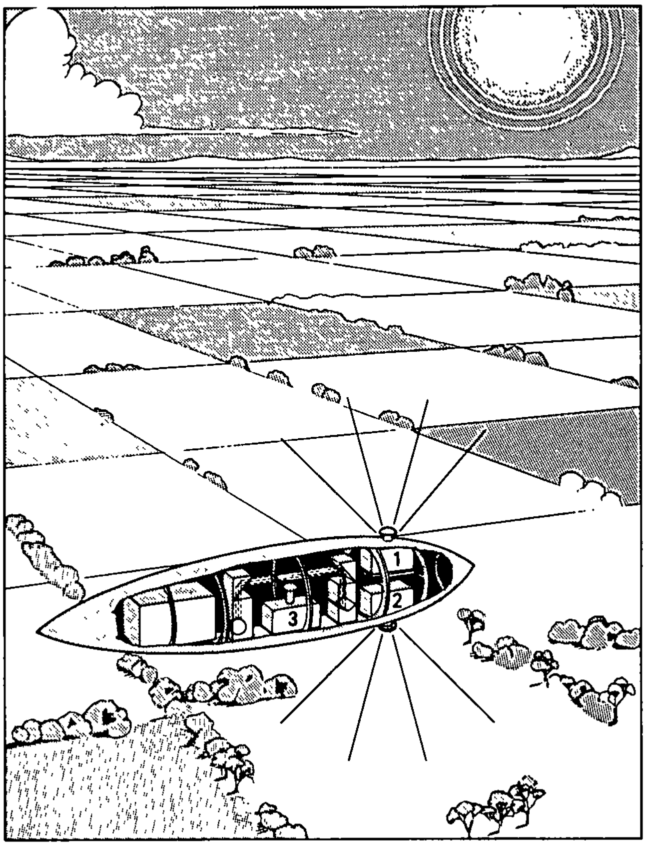


Fig. 1-1. Artist's conception of contrast transmittance monitor.

2. COMPLETION STATUS

As illustrated in Fig. 1-2, it was necessary to prematurely terminate the development of this prototype device after only sixteen months of the proposed twenty-four month program. As a result, the original design and fabrication schedules were revised in late FY82 in an attempt to optimize the achievable end item. Thus, the miniaturized nephelometer development received maximum priority for sub-assembly completions, and the simpler sky and terrain scanner system was put on hold. The following paragraphs describe the final completion status of each of the system components.

2.1 Multi-Channel Nephelometer Assembly

The function of the multi-channel nephelometer is to provide measurements identifying the magnitude of the atmospheric volume scattering coefficient $s(z)$ and the shape of the corresponding volume scattering function $\sigma(z,\beta)$. Since substantial informational redundancy was desired from the instrument's measurements, as was com-

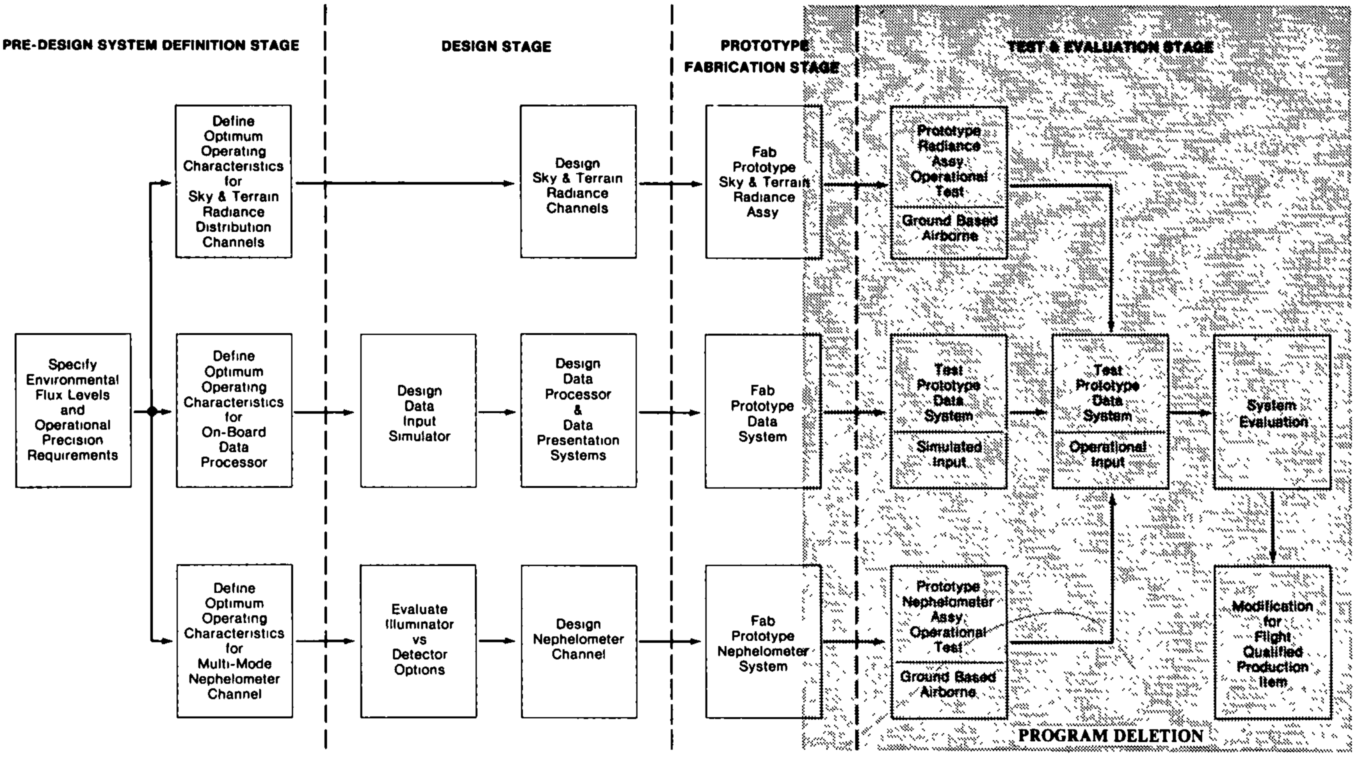


Fig. 1-2. General program plan for prototype contrast transmittance monitor.

mented upon in Johnson (1982), the configuration illustrated in Fig. 2-1 was established for the final prototype. This line drawing identifies the major operational components of the device, and Fig. 2-2 illustrates the as-built nephelometer assembly.

There were several minor modifications to the optical designs used in the nephelometer projector and receiver assemblies between the mock-up and prototype stages. These changes were made for the convenience of commercial availability, as well as for specific technical purposes. The resultant optical designs for these sub-assemblies are illustrated in Figs. 2-3 and 2-4. There were no changes between mock-up and prototype in the selection of illuminator and detector components. The EG&G model FX-132 Xenon flashtube was retained as the illuminator, and the EG&G model HUV-4000B detector was also retained. The as-built configurations of the projector and detector/receiver sub-assemblies are illustrated in Fig's. 2-5 & 2-6.

In the photograph of Fig. 2-2 one notes the absence of the integrating channel shown in the line drawing of Fig. 2-1. The fabrication of this specialized irradiometer was deferred in favor of the directional channels when the program termination was rescheduled. This seemed a reasonable option since there were no substantial problems anticipated in the implementation of the irradiometer designs and it could be completed and installed with only a moderate increment of additional expense.

The mechanical design of the five prototype detector assemblies, *i.e.* the four directional channels plus the projector's monitor channel, was established to provide maximum interchangeability among the individual components and also among the five sub-assemblies. Also, in order to simplify assembly, hook-up and checkout procedures, no attempt at package miniaturization was attempted. The goal was to achieve an operational test-bed within the constraints of reduced time and dollar resources. This goal was not achieved, however the additional increment of effort needed is small.

2.2 Fisheye Scanner Assembly

The design concept for the new compact scanner, as with the nephelometer, was slanted toward a low power, no moving parts system. Thus as discussed in Johnson (1982), a staring fisheye imager was chosen as the most attractive packaging option. A mock-up assembly, illustrated in Fig. 2-7, using the Soligor fisheye conversion lens in conjunction with an image plane array of EG&G HUV series detectors was tested and found adequate, as reported in the earlier companion report.

Since the mock-up scanner performed satisfactorily, no substantial design changes were contemplated for the subsequent prototype device. Fabrication of new, prototype assemblies was deferred pending completion of the nephelometer system in order to conserve resources and maximize nephelometer completion.

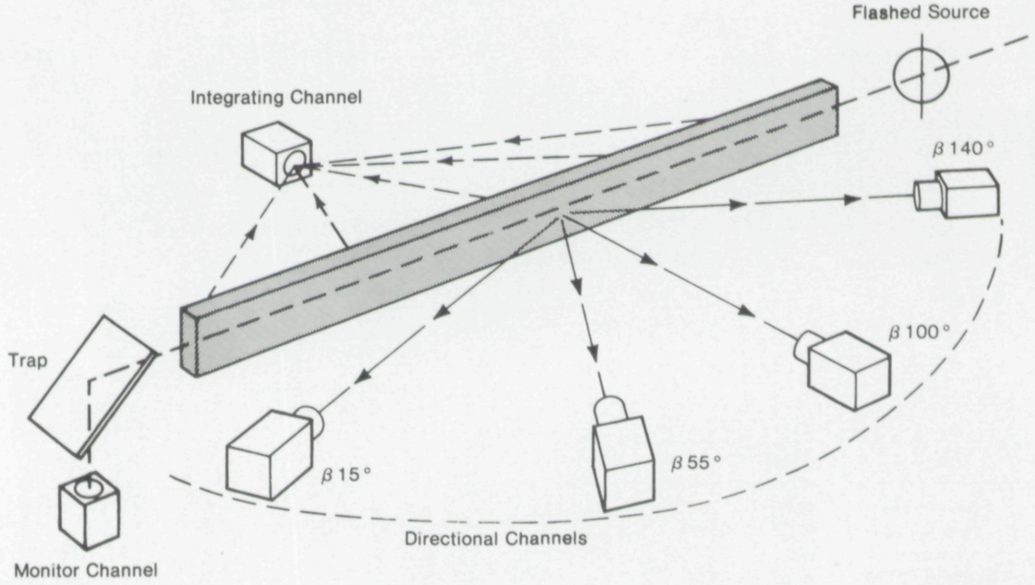


Fig. 2-1. Compact nephelometer - basic geometry.

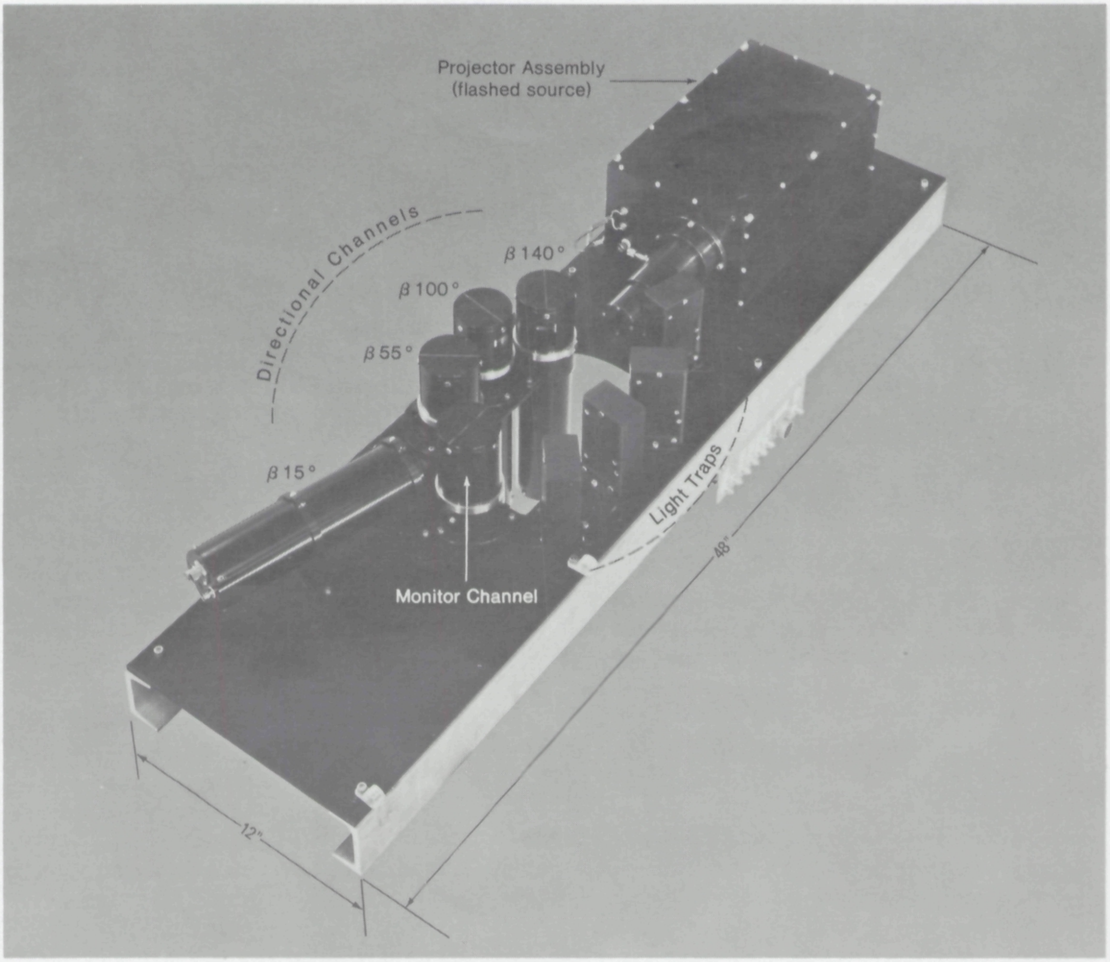
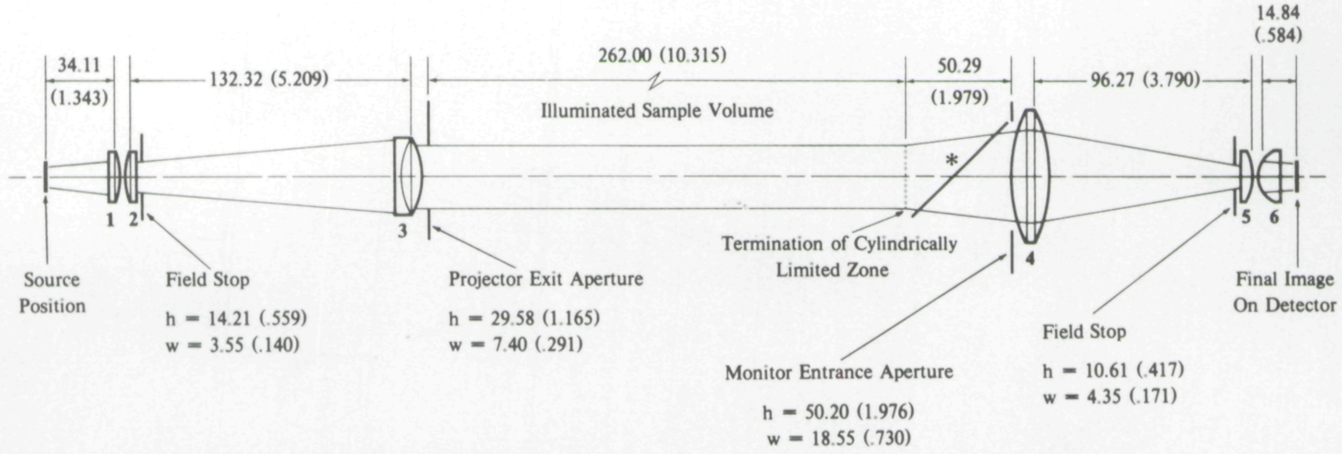


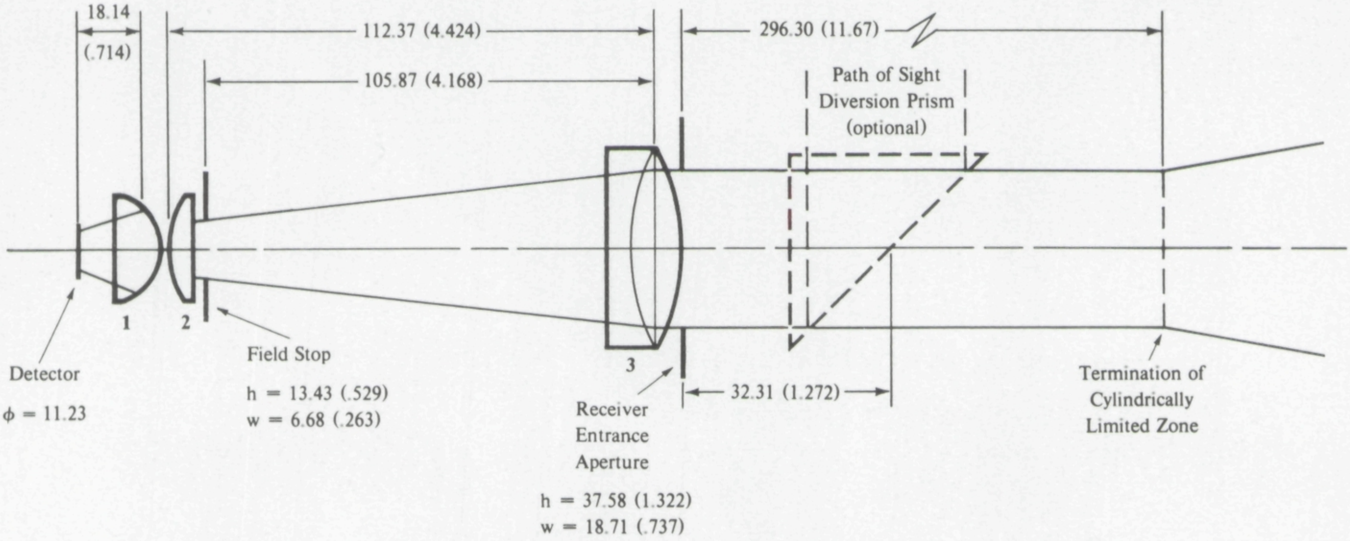
Fig. 2-2. Compact nephelometer - as-built assembly.



Lens No.	Lens Type	f = (mm)	f_b = (mm)	ϕ = (mm)
1	Plano-Convex	40.0	36.5	22.4
2	Plano-Convex	80.0	77.7	22.4
3	Achromat	85.0	-	36.0
4	Symetrical-Convex	70.0	64.4	60.0
5	Plano-Convex	40.0	36.5	22.4
6	Aspheric	18.0	11.4	24.0

* Projector Beam Attenuation
And
Direction Diversion Mirror
(shown in folded view)

Fig. 2-3. Prototype nephelometer projector/monitor. Optical design #39. Dimensions in millimeters (inches).



Lens No.	Lens Type	f = (mm)	f_b = (mm)	ϕ = (mm)
1	Aspheric	18.0	11.4	24.0
2	Plano-Convex	105.0	102.8	25.0
3	Achromat	78.0	-	46.0

Fig. 2-4a. Prototype nephelometer detector/receiver - directional. Optical design #39. Dimensions in millimeters (inches).

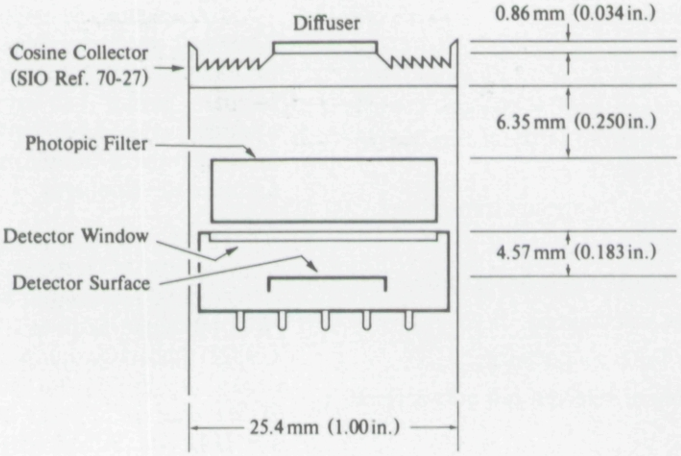


Fig. 2-4b. Prototype nephelometer receiver - integrating. Dimensions in millimeters (inches).

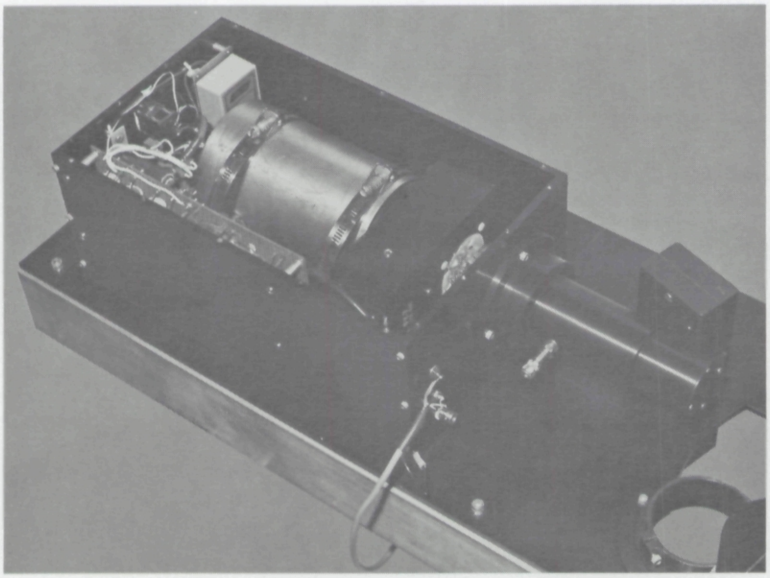


Fig. 2-5. Prototype nephelometer projector sub-assembly, as-built configuration.

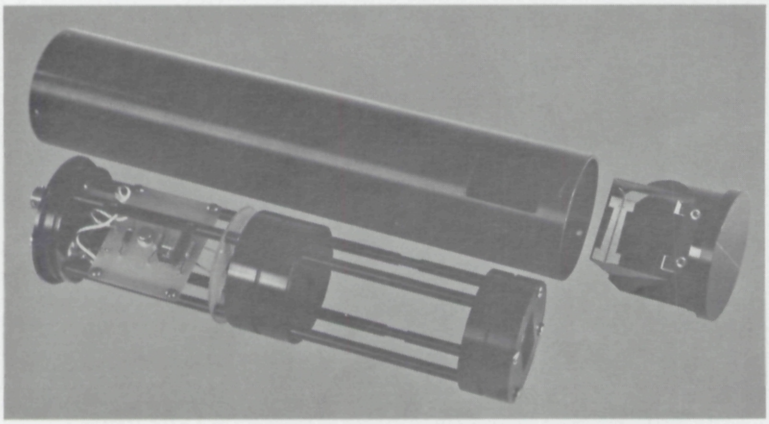


Fig. 2-6. Prototype nephelometer detector/receiver sub-assembly, as-built configuration.

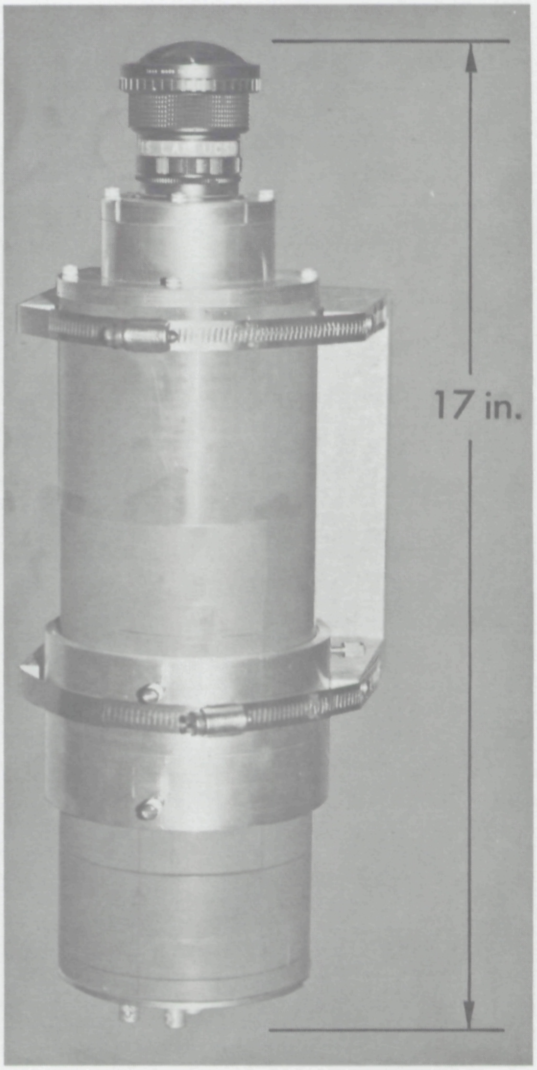


Fig. 2-7. Fisheye scanner mock-up.

2.3 On-Board Computer System

The on-board computer system associated with this instrumentation package has been built and assembled in keeping with the general plan outlined in Johnson (1982). The system functions are summarized in the listing below.

1. Accept the raw data stream from each transducer.
2. Store raw data on tape for later retrieval.
3. Convert raw data into usable engineering units.
4. Perform pre-determined calculations.
5. Store computed values for later retrieval.
6. Provide real-time display of selected raw and derived values.
7. Perform associated housekeeping to enable actions 1-6.

The general system outline is diagrammed in Fig. 2-8. This illustration from Johnson (1982) indicates the intentional redundancy between the in-flight data collection configuration (semi-automatic mode), and the In-lab test and development configuration (fully interactive mode). The as-built configuration resulting from this plan is shown in Fig. 2-9.

A general description of the Chieftan 6809 Computer and the Memodyne M-80 tape recorder was included in Johnson (1982) and thus will not be elaborated upon further. Suffice it to say that both of these commercially available units have performed well, as anticipated, and are currently in limited use awaiting further interface and software development.

The Vis Lab Signal Conditioner, Multiplex and Transfer (SCMT) Panel, and the In-flight Fixed Display (IFD) Panel are custom built units, and thus might benefit from moderate additional comment. As noted in Johnson (1982) these two hardware items are not separate black boxes, but in fact the IFD panel is the front face on the SCMT chassis. The as-built configuration of the composite IFD and SCMT assembly is illustrated in Fig. 2-10. An enlarged front view of the IFD is shown in Fig. 2-11 to more clearly illustrate it's color coded, functional layout. These as-built functions may be compared with the original design concept shown in Fig. 2-12.

The 6809 micro-computer is shown in Fig. 2-13 merely to illustrate its general configuration and the relative ease with which it lends itself to structural modification. Selected functional characteristics are summarized in Appendix A.

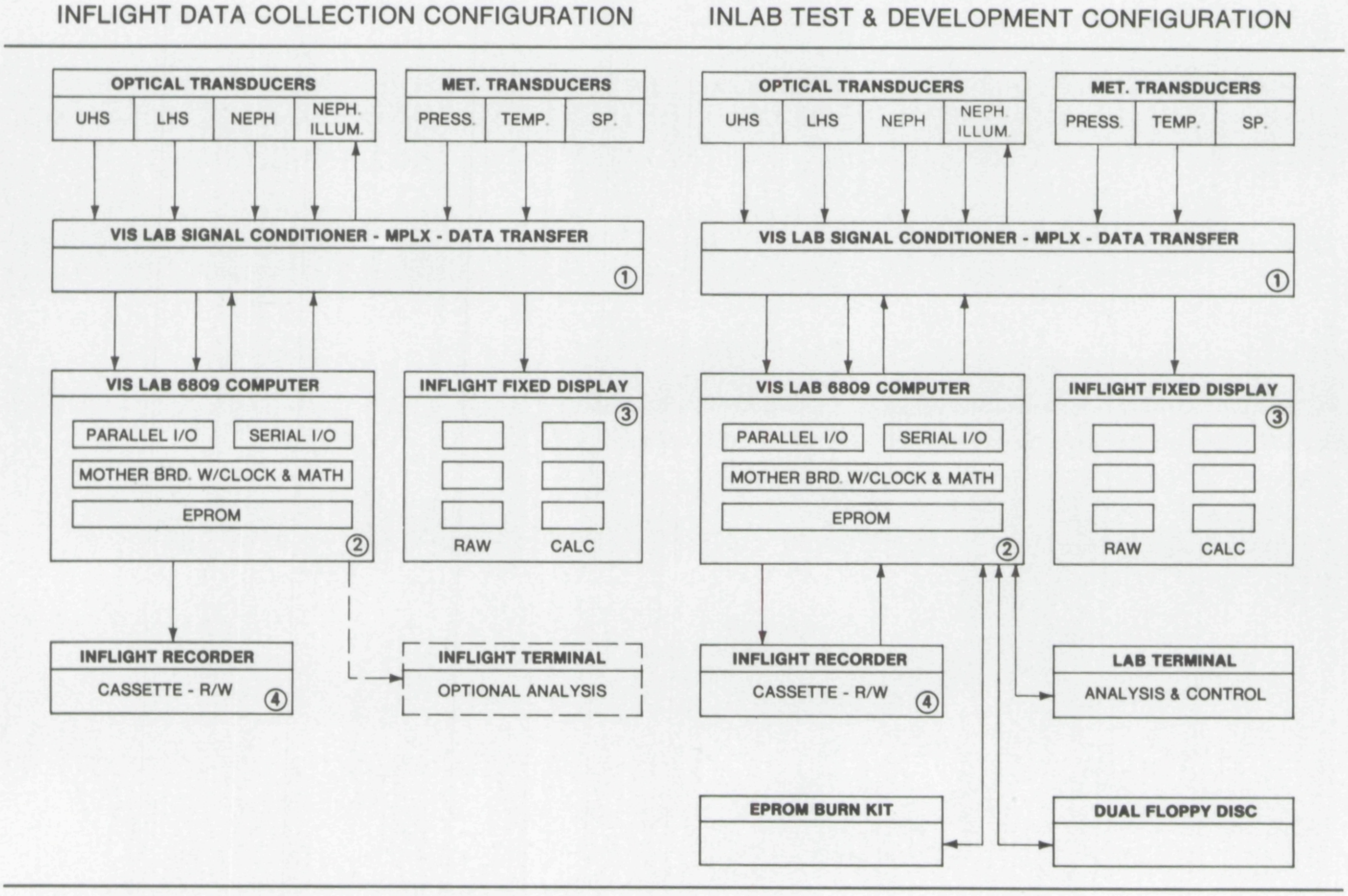
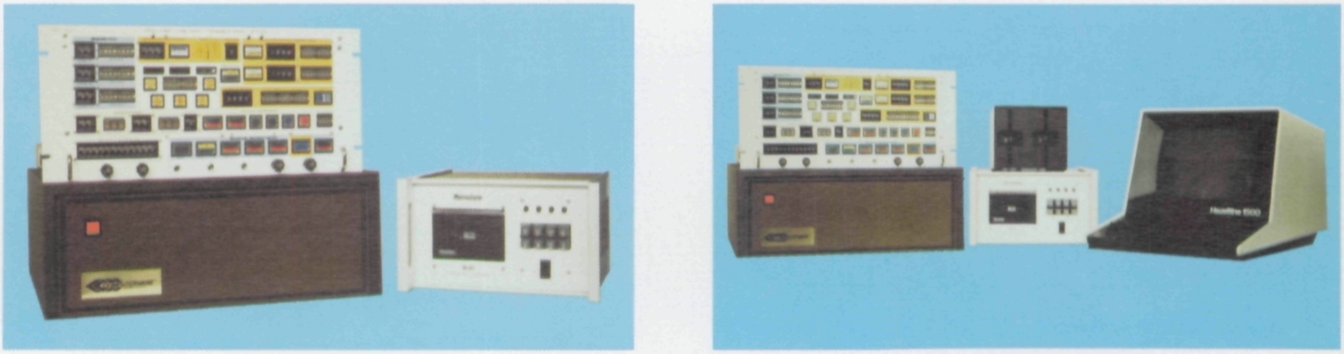


Fig. 2-8. On-board computer - preliminary layout.



a. In-flight configuration.

b. In-lab configuration.

Fig. 2-9. On-board computer system - as-built configuration.

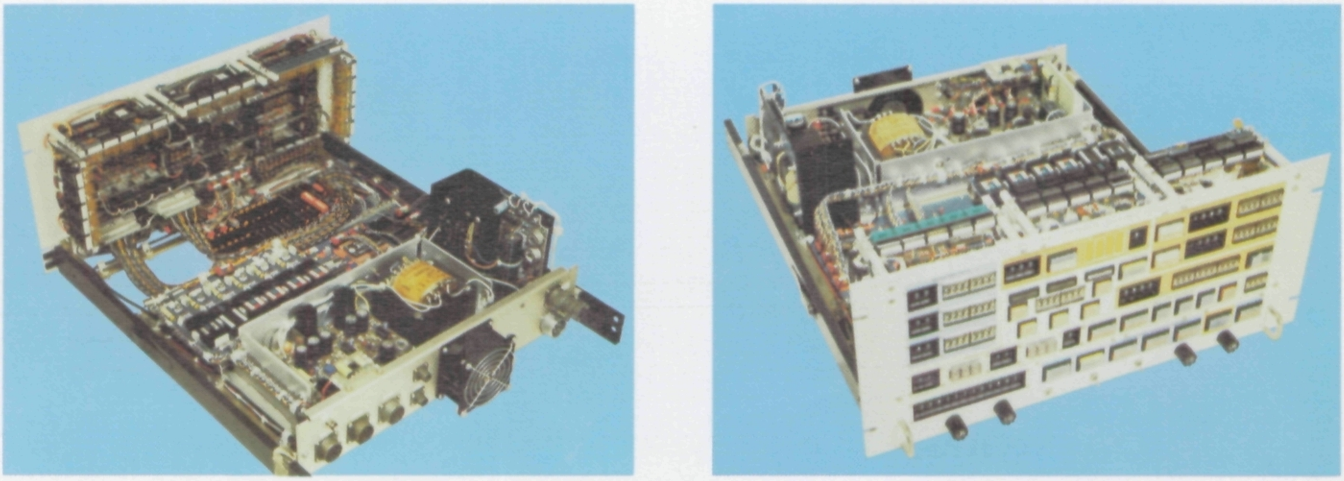


Fig. 2-10. Composite IFD/SCMT assembly - as built configuration.

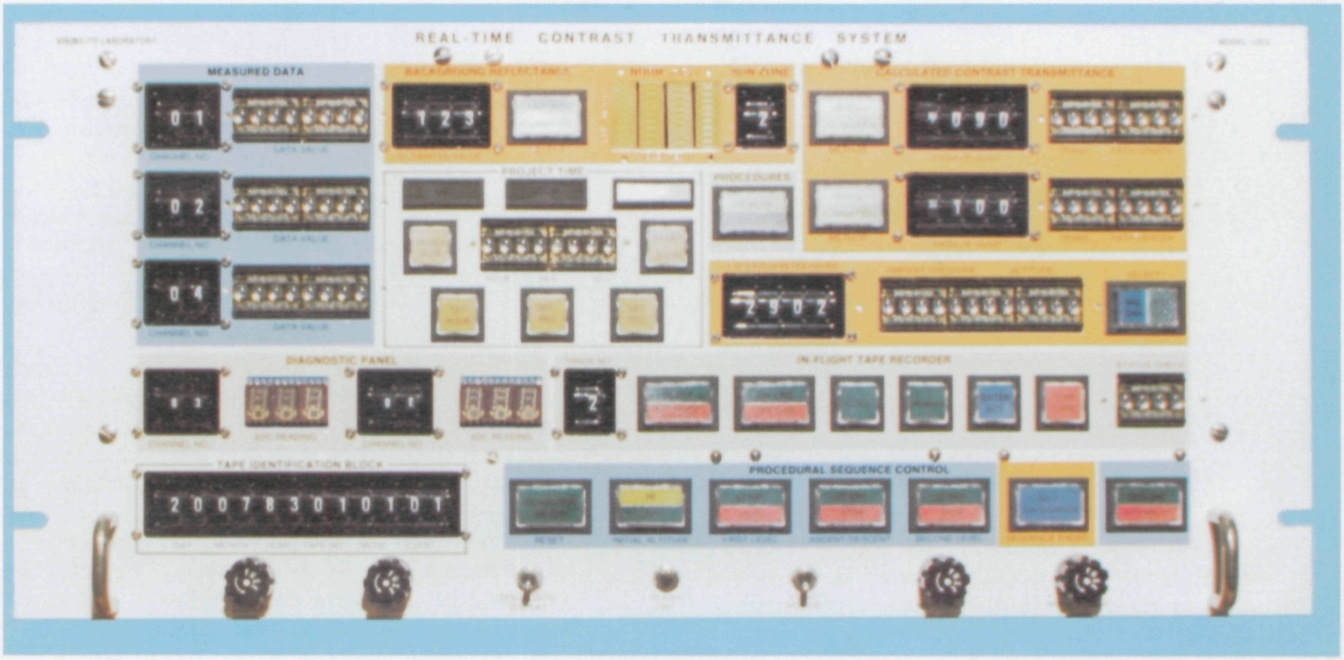


Fig. 2-11. In-flight control panel - as built configuration.

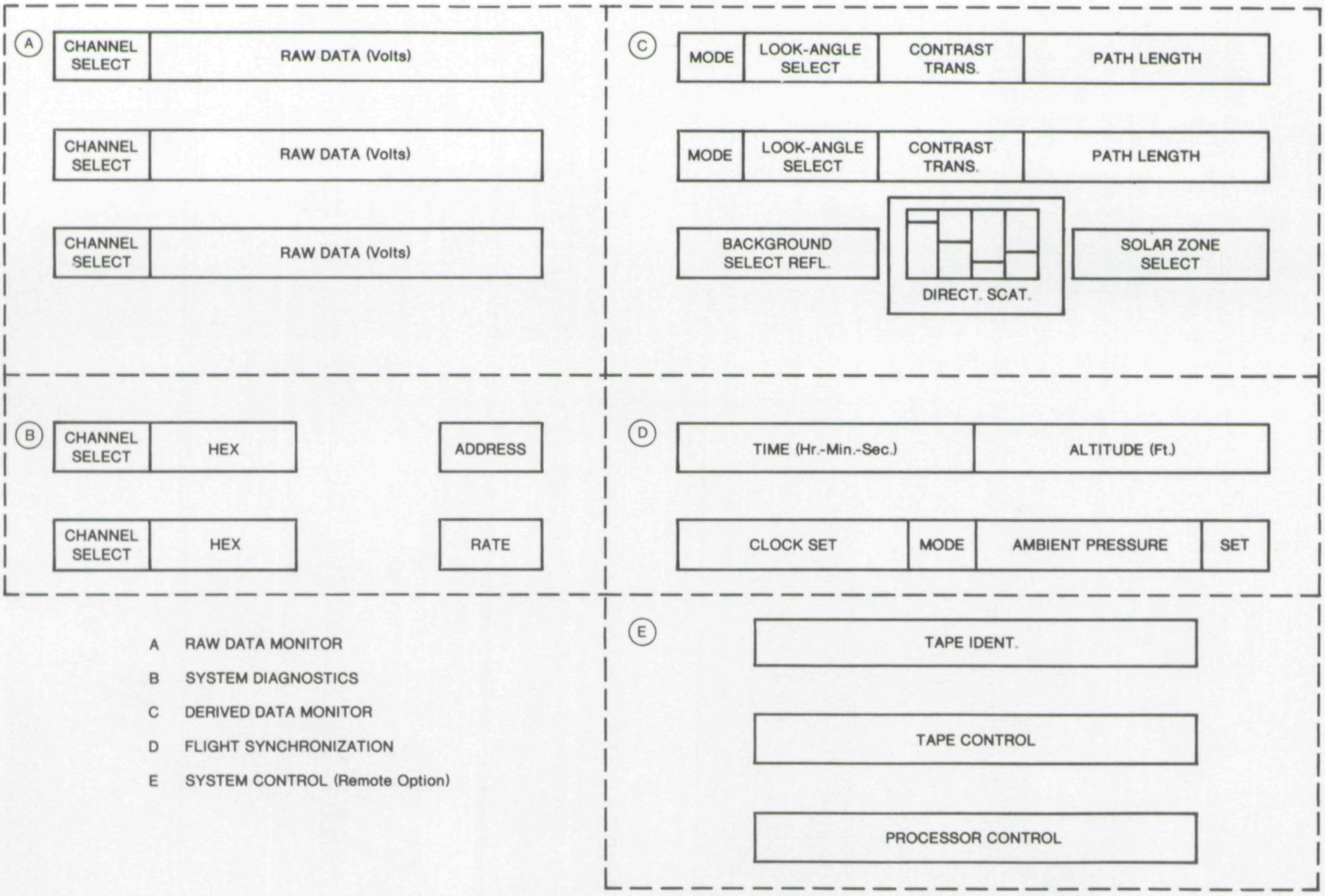


Fig. 2-12. In-flight control panel - functional layout.

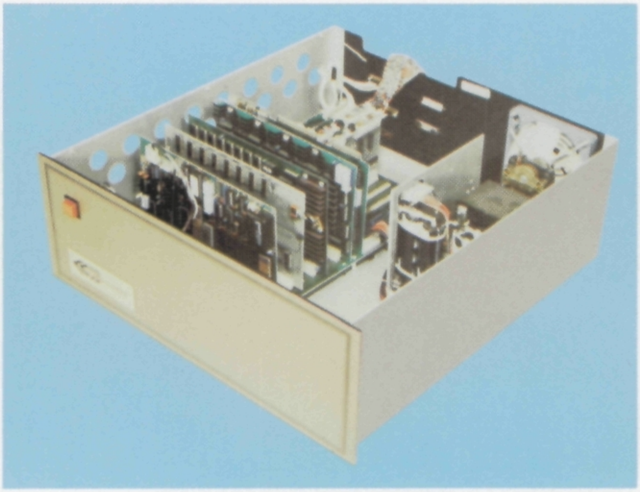


Fig. 2-13. Chieftan 6809 computer.

The functional relationship of the IFD/SCMT chassis with other system components is illustrated schematically in Fig. 2-14. In this pictorial representation, the data flow is basically from left to right, originating in the various transducer sub-assemblies on the left, through the IFD/SCMT chassis to the microprocessor and recording elements on the right. Some basic operational functions are summarized in the following paragraphs.

1. *Timing Cycle.* A basic data-taking cycle is programmed into the unit by means of dip switches. A nominal time duration for this cycle is one second. The cycle must be slow enough to allow for scanning and A/D conversion of all of the data input channels, as well as allowing time for the 6809 processor to accept the data. The basic timing and control logic provides for the channel addressing, MDAS conversion pulse, flash lamp triggering pulse, etc. This timing cycle runs continuously and is independent of program characteristics.
2. *Flash Lamp & Charge Amplifier Control.* A second function of the timing cycle and control logic is to initiate the firing of the flash lamp in the nephelometer projector, and to reset the integration cycle of the charge amplifiers. The charge amplifiers are cycled twice during each data cycle. The first cycle is without the lamp being flashed, and the second is simultaneous with the lamp flash. In this way, non-random noise can be identified and removed from the nephelometer detector signals.
3. *MDAS.* This sub-element is a Miniature Data Acquisition System under control of the main tim-

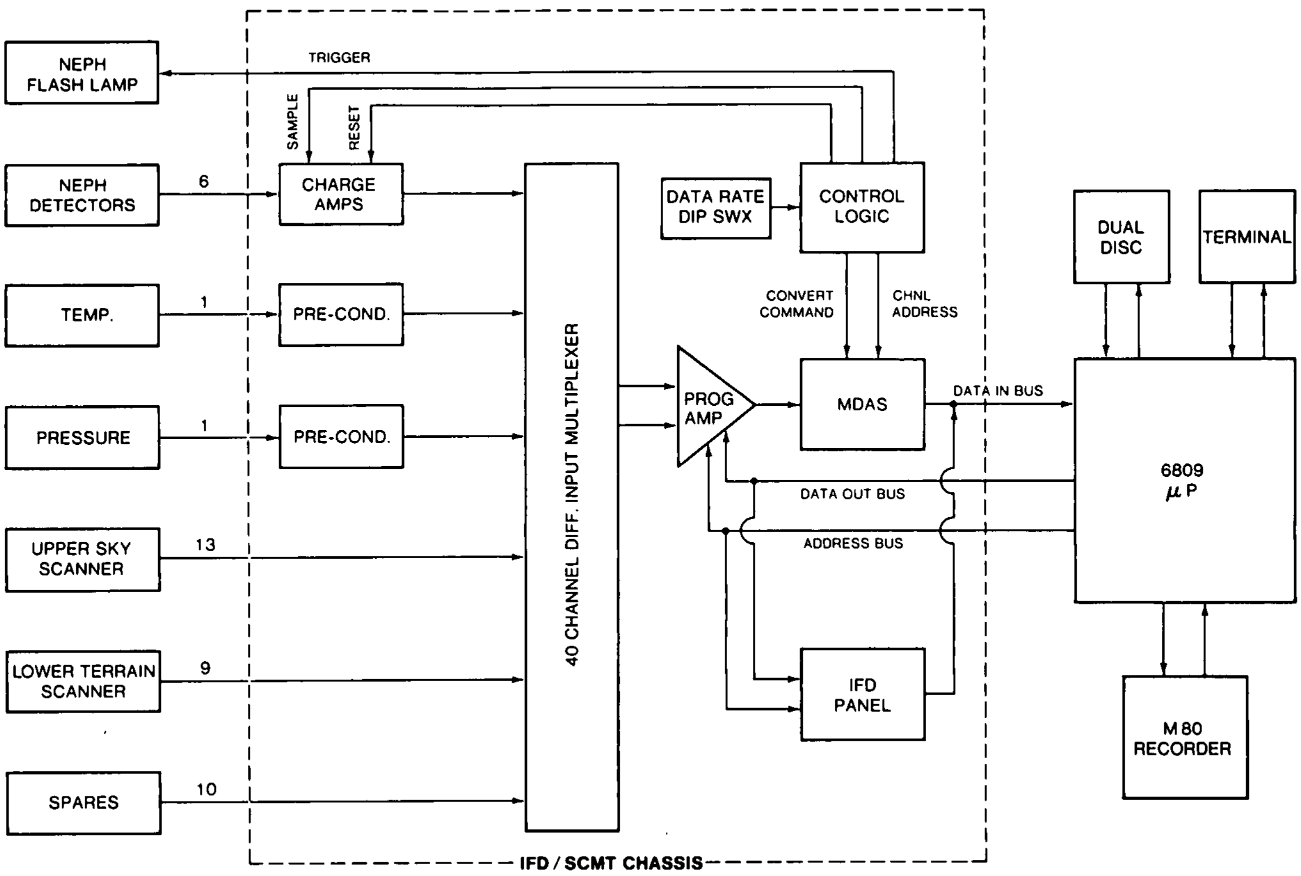


Fig. 2-14. Functional block diagram - in-flight computer system.

ing cycle. Whenever data from a given transducer channel is available in digitized form, a control pulse is sent to the 6809 to initiate or enable the data transfer. The resolution of this sub-system is twelve bits, which translates into one part in 4096. However, in this application, the system is used in a bipolar fashion in order to handle offsets, so the resolution is reduced to one part in 2048.

4. *Programmable Amplifier.* To aid in the overall signal conditioning process, auto-ranging is employed through the use of an amplifier whose gain is controlled over a range from unity to 256. This gain is set by the 6809 micro-processor so that the signal from any channel can be adjusted to an optimum level for maximizing resolution.

5. *IFD Panel.* The In-Flight Display panel provides for input to the overall system by the operator, as well as displaying current system status. It is completely under the control of the 6809 microprocessor. The panel is continuously being scanned by the microprocessor to detect changes (if any) in any of the systems basic input parameters. Upon change in any of the more critical input parameters, a computer interrupt occurs allowing the updated information to be incorporated into the control or computational sequence. Typical examples of the interrupt sequence being implemented are changes in the mode switches by which the operator identifies the individual phase of the flight profile, changes in the terrain reflectance selection, or changes in the altimeter calibration.

   As shown in Fig. 2-11, output displays are provided for simultaneous inspection of any three input channels and any two calculated contrast transmittances.

   Continuous displays of time, pressure and derived altitude are also available, as are a variety of system troubleshooting readouts.

At the termination of this development program, all of the components related to the system configurations shown in Fig. 2-9 had been acquired and/or fabricated, but not fully integrated operationally. Thus, the goal of any subsequent effort must be full system integration and checkout. This should be a reasonably simple task since no fundamental technical problems were encountered during the development effort.

3. SYSTEM REVIEW

As discussed in the preceding interim report AFGL-TR-82-0125, Johnson (1982), and subsequently in this Final Report, a simple yet relatively smart electro-optical system has been devised to do real-time monitoring of the optical state of the atmosphere. The system concept has been built around three solid state, no moving parts, transducer assemblies interfaced with a small dedicated microprocessor that can control the system in either a semi-automatic, or an operator interactive mode. This concept has resulted in the development of a multiple purpose system, capable of jointly supporting tactical commanders, meteorological forecasters, and researchers involved in studies of multi-spectral atmospheric contrast transmittance. The device, while primarily intended for airborne application within the lower troposphere, is easily adaptable for static ground based applications in the determination of near surface optical properties. Thus, it can be equally useful in providing relatively inexpensive flight data appropriate for the validation of new or improved modelling techniques, as well as providing the means for significantly shortening the necessary predictive window required for the meteorological support of time-critical field operations.

The development status at the conclusion of this shortened contract interval is such that; a) each of the system sub-assemblies has been evaluated in an operational mock-up configuration, b) each has performed adequately to indicate technical feasibility, and c) the miniaturized nephelometer and on-board computer systems have been developed and fabricated to the prototype hardware stage.

The compact, multi-channel nephelometer, illustrated in Fig. 2-2, is near completion. Electrical hook-up and fabrication of the irradiometer channel are the only remaining tasks to be completed in order to enable full operational testing. The enclosing shroud, which is contemplated for airborne use, is a fiberglass housing whose fabrication has been deferred pending full system check-out and operational debugging. The potential utility of this nephelometer system is so high that it is recommended that every effort be made to assure its completion.

The staring fisheye scanner which performed well in this mock-up configuration, has not been updated to the prototype brassboard configuration. New image plane diffuser plates were fabricated, but completion of the upgraded configuration was deferred in favor of more fully completing the compact nephelometer. Additional analysis was accomplished however to aid in the optimization of the sun zone diffuser pattern. Based upon these analyses (similar to but more extensive than those contained in Appendix B of Johnson (1982)) a four segment sun zone was determined to be best for the discrete detector configuration. However, an engineering mock-up of a GE TN2200 128x128 scanning array camera confirmed the opinion expressed in the preceding interim report that full implementation of a scanning array detector was a highly desirable alternative option. It is recommended that subsequent development of this overall system include a further evaluation of the CID solid state camera as the primary fisheye detector. There is good reason to believe that an airborne 4π radiometer using this class of detection might readily be developed not only to perform the integrations necessary for contrast transmittance determinations, but also to address the determination of atmospheric single scattering albedo.

The in-flight computer system was built in accordance with the interim report outline and is ready for full system integration. Software development has proceeded to the level necessary for handling the signal outputs from the directional nephelometer channels and ratioing them with the output from the projector monitor channel. Individual channel integrations to compensate for the pulsed nature of the nephelometer illuminator are hardwired into the IFD/SCMT chassis and thus need not be handled by software. Software development for the calculation of slant path contrast transmittances was established for the Ratio Method, described in Johnson (1982), but deferred for the more difficult Summation Method. Additional software development to enable full system check-out and debugging is in fact the major task remaining prior to full implementation of the system.

The need for a device of the type described in the preceding paragraphs to aid in the assessment of the atmospheres influence upon E/O system performances still exists. Its potential utility in support of both operational and research scenarios is clearly evident from its demonstrated capability in the determination of 4π radiance distributions and atmospheric scattering coefficient profiles from which one may readily derive the atmospheres characterizing optical properties. It is strongly recommended that every possible effort be made to enable the completion and deployment of this prototype device.

4. ACKNOWLEDGEMENTS

The development of this system concept has been built upon the long term experimental program of airborne measurements of optical atmospheric properties conducted by the Visibility Laboratory staff under the sponsorship of the Optical Physics branch of the Air Force Geophysics Laboratory.

The technical design and engineering prototypes have been provided by Mr. R.L. Ensminger and G.F. Simas of the Visibility Laboratory's electronic design group, and by Mr. T.J. Petzold, the Laboratory's optical design specialist. Ms. J.I. Gordon provided much of the analytic support in developing the techniques for evaluation of the sun and sky zone selections.

5. REFERENCES

Duntley, S.Q., R.W. Johnson, and J.I. Gordon (1976), "Airborne Measurements of Optical Atmospheric Properties in Northern Germany", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 76-17, AFGL-TR-76-0188. NTIS No. ADA 035 571.

Johnson, R.W. (1982), "An Experimental Device for Real-Time Determination of Slant Path Atmospheric Contrast Transmittance", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 82-27, AFGL-TR-82-0125.

APPENDIX A

Chieftan 6809 Computer
Selected Functional Characteristics

The Chieftan 6809 computer used as the host controller for the multi-channel radiometer system described in AFGL-TR-82-0125 contains a basic motherboard (SS-50 Buss) with nine slots for the CPU board, memory, floppy disc controller, EPROM board, etc. In addition, eight I/O slots are provided for serial and parallel interfaces, or other specialized function boards that one might desire. *i.e.* video digitization, A/D conversion, etc.

The separate floppy disc assembly contains two double density, double sided disc drives having a combined storage capacity of 732K bytes.

A review of several system characteristics is contained in the following brief outline.

1. RAM Memory (2-M-32-X)

   Contains 64K bytes, bank selectable. Only 56K bytes are usable because of memory space being occupied by I/O and the system monitor.

2. CPU Board (SCB-69)

   The CPU board with floating point option uses the Motorola 6809 microprocessor chip running at 2 MHz (4 MHz optional). Additional features include,

   a. 1K byte of scratch pad RAM
   b. 20K bytes of EPROM (includes system monitor)
   c. An on-board 9511 Floating Point Processor Chip
   d. Real-time clock with battery back-up (MM 58167)

   The 9511 chip is a very useful device for this application in that operators and operands can be loaded into the 9511 stack and the resultant pulled out of the stack, all under direct program control. Thus most arithmetic operations can be performed without extensive software routines.

3. Disk Controller Board (DCB-4)

   This controller can accommodate up to four 5-1/4 inch or 8 inch drives. Single or double density, single or double sided formats can be selected.

4. EPROM Board (S-32)

   This board has a memory capacity of 32K bytes. Either RAM or ROM memory can be utilized in 4K byte blocks. Additionally, the board is selectable in two 16K byte sections so that 32K, 16K or zero memory is enabled.

5. I/O Slots

   There are eight I/O slots available in this computer. Two types of boards are typically employed. The first is a selectable baud rate serial board with two serial RS232 ports. The second is a parallel board having two parallel eight byte ports each with handshake lines. These ports can be connected for either input or output. Both sets of cards can be interrupt driven if desired.

   An EPROM burner card is part of the system and may be plugged in to any I/O port. Either 2708 (8K) or 2716 (16K) EPROMS can be programmed under program control. Erasure of the EPROMS for reprogramming is accomplished through the use of a standard UV source which is part of the Laboratory in-house inventory.

APPENDIX B

VISIBILITY LABORATORY CONTRACTS AND RELATED PUBLICATIONS

Previous Related Contracts:
F19628-73-C-0013, F19628-76-C-0004

PUBLICATIONS:

Duntley, S.Q., R.W. Johnson, J.I. Gordon, and A. R. Boileau, "Airborne Measurements of Optical Atmospheric Properties at Night", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 70-7, AFCRL-70-0137, NTIS No. AD 870 734 (1970).

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Duntley, S.Q., R.W. Johnson, and J.I. Gordon, "Airborne Measurements of Optical Atmospheric Properties in Northern Germany", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 76-17, AFGL-TR-76-0188, NTIS No. ADA 035 571 (1976).

Duntley, S.Q., R.W. Johnson, and J.I. Gordon, "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Spring 1976", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 77-8, AFGL-TR-77-0078, NTIS No. ADA 046 290 (1977).

Duntley, S.Q., R.W. Johnson, and J.I. Gordon, "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Fall 1976", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 78-3, AFGL-TR-77-0239, NTIS No. ADA 057 144 (1978a).

Duntley, S.Q., R.W. Johnson, and J.I. Gordon, "Airborne Measurements of Atmospheric Volume Scattering Coefficients in Northern Europe, Summer 1977", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref. 78-28, AFGL-TR-78-0168, NTIS No. ADA 068 611 (1978b).

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Johnson, R W and J I Gordon, "A Review of Optical Data Analysis Related to the Modelling of Visible and Optical Infrared Atmospheric Properties", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref 83-5, AFGL-TR-82-0086 (1981)

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Johnson, R W and W S Hering, "An Analysis of Natural Variations in Measured European Sky and Terrain Radiances", University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, SIO Ref 82-6, AFGL-TR-81-0317 (1981b)

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