GOODYEAR AEROSPACE

CORPORATION

AKRON, OHIO

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TECHNICAL PROPOSAL

RFP 159

BIF-048/001-2311-68

GAP-5017

28 June 1968

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1.0 BACKGROUND

1.1 BETA Subsystem General Description

The BETA Subsystem consists of a Sensor package containing an optics system which images the 2.8 inches diameter input image on the photocathode of the CORRELATRON* and the peripheral electrical items which must be in close proximity with the CORRELATRON, and an Electronics Control Assembly which contains the remaining electronics required by the Subsystem. The Electronics Control Assembly accepts the system input power and commands, provides the system output signals and supplies and receives the Sensor power and signals during system operation. The Sensor and Electronics Control Assembly are interconnected by a single cable.

In order to obtain image rate information the IVS uses the CORRELATRON in a closed loop as shown in Figure 1. The electron image in the CORRELATRON is nutated by magnetic deflection fields from the orthogonal α and β,(α and β are the correlation variables) deflection system. Quadrature nutation signals are provided by a nutation oscillator to the deflection system and as reference signals to the phase discriminators. The resulting CORRELATRON output signal at the nutation frequency is amplified and phase-discriminated with respect to each quadrature nutation reference. The outputs of the phase discriminators are the derivatives of the correlation function with respect to α and β and thus equal zero at the maximum of the correlation; i.e., the position of best correlation. The discriminator output signal is used to close the loop around the CORRELATRON through an integrator and deflection system in each axis. This causes the electron image to be deflected to the position of best correlation.

The outputs of the integrators are, therefore, proportional to α and β and thus the inputs to the integrators are the derivatives of α and β with respect to time. By definition of the correlation function, $\frac{d\alpha}{dt}$ and $\frac{d\beta}{dt}$ are proportional to the image rates on the face of the CORRELATRON.

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* Trademark, Goodyear Aerospace Corporation, Akron, Ohio 44315.

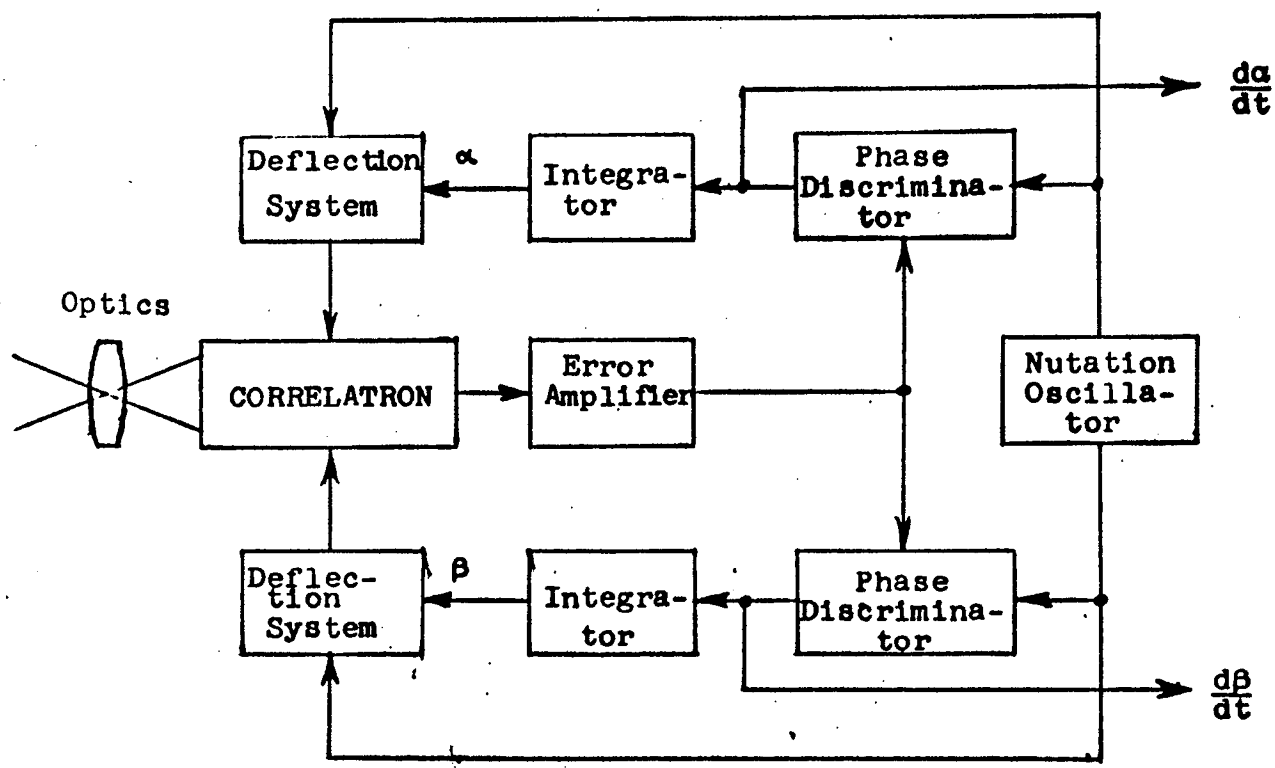

Figure-1-1 - **Image Motion Sensor Function Diagram**

The preceding discussion presents a very much simplified description of the IVS performance and does not attempt to describe the actual mechanization which will be discussed later. The discussion serves only as an introduction to the IVS theory of performance.

1.2 Origin and Background of Proposed Design Including a Discussion of Development Work to Date

In 1947, GAC began the development of the MX-778 ATRAN* guidance system for the TM-76A Mace Missile. This system used an automatic image correlation technique to register a real-time radar display with synthesized reference images. This contract effort continued throughout the 1950's and was supported by Corporate R&D programs to develop improved correlation implementations. One approach consisted of a vidicon optical sensor and an electrical storage tube correlator, which led to the award of Contract AF33(657)-8811 in April 1962 from Wright-Patterson Air Force Base, Dayton, Ohio. This contract was for the development of a high accuracy passive V/H sensor, which could control the motion of a film platen of an aerial camera in order to minimize image smear during exposure.

Evaluations of this type of correlator, which sequentially examined the image parameters by a line-by-line scanning spot process, indicated that heavy smoothing of the output signal was required in order to achieve a signal-to-noise ratio which approached that obtainable from optical projection correlators which simultaneously accommodated all the image parameters contained in the field-of-view. Accordingly, GAC initiated a Corporate R&D program to develop an electronic implementation of the optical correlator. This initial work utilized an ITTIL Model 231 Storage Image Tube, and led to the filing of patent 3,290,546 in October 1962. This patent discloses a sensor tube containing a photocathode for converting the optical input image to a corresponding electron image, a storage technique for temporarily recording the geometric and contrast parameters of an initial input image, a deflection technique for electronically displacing a later input image with respect to the initial stored input image, an electron modulation technique to simulate image multiplication, and a signal collection technique to simulate integration.

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* Trademark, Goodyear Aerospace Corporation, Akron, Ohio 44315.

In May 1963, GAC received Contract AF33(657)-11090 from Wright-Patterson AFB, Dayton, Ohio to develop a Night-Velocity Over Altitude Ratio Sensor. This program demonstrated that a fast response passive image motion sensor was feasible for low illumination level applications, by utilizing the improved S/N available from electronic simultaneous area correlation. Concurrent with this contract effort, GAC Corporate R&D funds were provided to ITTIL, Ft. Wayne, Indiana, to develop a practical tube configuration. The first such tube was delivered in February 1965, and was designated the CORRELATRON.

Also in February 1965, GAC received Contract AF33(615)-2404 from Wright-Patterson AFB, Dayton, Ohio, to develop a CORRELATRON sensor capable of automatically controlling the image motion compensation, the focus, and the exposure of an aerial camera. During this same period, GAC was engaged in discussions with SAFSP, Los Angeles, California, concerning an application for a very high accuracy image motion sensor. This application required that the sensor be an integral component of a Navigation and Control Subsystem, and that it senses light diverted from an image on a film platen of a camera to generate viewer image rate correction signals for an Optical Tracking Mirror Drive. These discussions indicated that the all-electronic CORRELATRON area correlator employing an internal closed integrator feedback loop was particularly well suited to the system requirements for: Low image rates, low image illumination, low image contrast, fast dynamic response, insensitivity to image changes, low power, low weight, high reliability, and long life. Accordingly, GAC received RFP 04-695-66-148 in September 1965, and was awarded Contract AF04(695)-914 in October 1965. This program required the demonstration of the feasibility of a frame mode closed loop IMC (Image Motion Compensation) device using the CORRELATRON. It consisted of an analysis of the IMC requirements for strip and frame mode cameras, and the design, fabrication, and demonstration of a laboratory simulator and IMC breadboard.

Following the successful demonstration of feasibility, GAC received Contract AF18(600)-2967 in July 1966. This contract continued until January 1968, and consisted of the further development of IVS techniques and implementations, and included: Coordination with Air Force/Aerospace and with GE; system analysis; component review, selection, and experimental evaluation; IVS breadboard fabrication; test and improvement; simulator improvement modifications; and system experimental evaluation.

On 8 September 1967, GAC received the subcontract 029B25006 from GE. This contract consisted of providing the IVS breadboard system fabricated under Contract AF18(600)-2967 for GE evaluation, provide field test support and develop, design, fabricate, assemble, test and deliver one IVS engineering prototype evaluation model for GE evaluation. This contract is still in effect and continues until the latter part of this year. Initial evaluations of the IVS breadboard have been completed and the prototype is presently being assembled.

1.3 Part O Design Status

The design of the Part O Engineering Prototype Evaluation Model (EPEM) is essentially complete and the fabrication and assembly phases are presently underway. The EPEM is a second generation breadboard or can be considered a first generation IVS which has design objectives to satisfy the space, weight, power and performance required of the subsequently designed IVS systems as defined by EC701A, Rev. 5. Testing of the IVS breadboard at GE indicated several areas of performance require improvement. Presently a model improvement program on the EPEM is underway in order to satisfy the performance requirements of the specification.

The Part O program also includes a study phase which is presently engaged in (1) evaluating possible trade-offs in performance, (2) analyzing possible methods applicable to image specification techniques, (3) math modeling to aid in performance prediction of the IVS, and (4) investigating cloud detection techniques and the effects of ground obscurations on the IVS performance. These studies represent the first phases of the study programs required for the proposed effort. Significant progress has been made in the aforementioned areas but much remains to be done before the results of the studies can significantly improve the IVS design.

2.0 ANALYSIS OF DESIGN AND TEST REQUIREMENTS

2.1 Design

The primary objective of the IVS design and development program, defined in the Work Statement WS 701E, dated 27 May 1968, is to satisfy the performance requirements of the specification EC701E, Rev. 6. The second most important design consideration is reliability and thirdly, safety. Of course, it is difficult to separate these latter two areas of effort, but if a trade-off must be made between these two areas it must be made in favor of reliability with all other considerations being equal. All other areas of design such as producibility, maintainability, logistics, schedule, etc., are subordinate to the above three mentioned areas. This does not mean to say that these subordinate areas of endeavor are not essential to the program but it does mean that performance, reliability and safety will be given primary consideration in performing all the subordinate tasks of the program.

It goes without saying, of course, that the single most critical item to be considered, and "followed to the letter", is security. Although this is usually not a part of a design effort, on this program it must be used as a guide and sometimes as a hindrance to a desired progress in order to control and restrict contacts with uncleared individuals. The cleared individuals on the program must constantly be aware of their responsibilities to the program from a security point of view and no breach of security must occur regardless of the seemingly urgency of the problem. This stringent security requirement is a restriction on the operation of the program personnel which is not normally placed on them and which must be constantly re-emphasized to them to keep all personnel alert to their responsibilities. It must be noted that the security imposed on this program places the entire responsibility for maintaining security on the individual, hence, the proper education of the individual in this area is imperative.

The IVS design task is one of developing and designing the next generation hardware of the Part O BETA Subsystem. The Part O hardware is scheduled for delivery 30 September 1968. The proposed

IVS system will be an improvement over the Part O system in the areas of performance, circuitry and packaging including the incorporation of a CFE A/D converter. Reliability, safety, weights, maintainability, power, etc. which were design objectives of the Part O program become design requirements on the proposed program and, therefore, a much more extensive effort is required in these areas. This additional effort will impose more restrictions on the design and development engineers with regard to these items than the previous program did which will result in a better system as far as the secondary program requirements are concerned. The defined program disciplines associated with the secondary objectives of the program, such as weights, power, reliability, etc., analysis and reports will assure compliance with the requirements for the areas of concern.

A study program is proposed to support the IVS design effort. This study program is a continuation of the Part O program studies in the areas of (1) Image Specification Techniques, (2) Performance Prediction Techniques, and (3) Cloud Obscuration Effects. This latter task was the cloud detection techniques study of Part O. Cloud detection is no longer a requirement, however, the effects of ground obscurations on the IVS performance must be known in order to determine the IVS performance under all anticipated operating conditions.

Updating and continuations of the Part O studies for design support are required in the areas of null accuracy, illuminance effects, center of power effects, theoretical system response and dynamic response, dynamic range and linearity versus accuracy. In addition, an error analysis task has been included in the proposed program which was not included in the Part O program. The results of the studies will serve to either verify or provide information for improving the IVS system performance.

2.2 Test

A development test program is required to support the IVS design effort. This test program will include the operation of the Part 0 EPEM breadboard and a GAC engineering model of the same configuration as the deliverable engineering models when it is available. The GAC engineering model will be used as a manufacturing tool after its performance has been verified. It will be used for checkout and verification testing of the acceptance tester, qualification tester and the deliverable test setup. Also, it will be used as a "standard" for comparison purposes with the test results obtained from the deliverable units. The GAC engineering model will be continuously updated to reflect the latest IVS design so its performance will be compatible with the hardware being delivered.

The development test program will also include the evaluation of various circuit configurations proposed for use in the IVS. The testing will include circuit performance evaluations under the temperature conditions and input power conditions stipulated in the specification EC-701A, Rev. 6. Special consideration will be given to minimizing power dissipation and defining the proper heat sink techniques to be employed for each component.

Hard testers will be obtained to support the proposed program IVS fabrication. These testers will include units for testing incoming components including the CFE A/D converter, electronic subassemblies such as multilayer boards, focus coils and power supplies, and IVS assemblies of the sensor and the electronics control assembly. The testers will be suitably designed so that subassembly and assembly trouble-shooting and repair can be accomplished with relative ease.

The qualification tester will be an acceptance tester with additional accessories required to operate the IVS during testing under the various required environments. System operation is required during such environmental tests as temperature cycling, and EMI. Performance evaluation testing of each IVS under test is required after exposure to each of the environmental conditions.

The IVS performance tests will be performed to the acceptance test procedure.

The qualification test procedure will define the power and scene input conditions to be used in operating the IVS during the exposure to the various environments. The critical performance parameters will be measured during these tests and an evaluation of the system performance made. Quick look reports will be forwarded to GE upon completion of test phase which will be after the IVS has been performance evaluated to the acceptance test procedure. GE will also be notified of any malfunction of the IVS detected during these tests.

Two IVS systems will be fabricated especially for the qualification test program because of schedule considerations. The qualification test required time span and the specified end date necessitate starting the test on 1 September 1969. Hard tooling and prime equipment processing and procedures will be used to fabricate these systems. Prior to starting the qualification testing, the units will be acceptance tested. The acceptance test will be performed on the prime equipment acceptance tester and will include the operability assurance tests defined in DR1100. Therefore, the qualification test program will be conducted on prime IVS units which have been accepted for delivery. Also, all test data accumulated during the qualification testing will be relatable to the original acceptance test data since the compatibility of the acceptance and qualification testers will be established prior to the start of testing.

3.0 DESCRIPTION OF POSSIBLE SUBSYSTEM IMPROVEMENTS

3.1 General

Several improvements to the IVS are presently under investigation and evaluation on the Part O program. These system changes are primarily concerned with improving the system performance in the areas of low light level, low scene contrast and scene scale changes due to changes in line-of-sight. The changes under consideration are

(1) CORRELATRON modifications,
(2) variable amplitude nutation,
(3) variable exposure control,
(4) magnetic zoom.

3.2 CORRELATRON Modifications

The modifications to the CORRELATRON which are presently under investigation are the incorporation of (1) a coarse collector mesh, and (2) a thicker dielectric storage mesh. The coarse collector mesh will increase the electron transmission of the CORRELATRON by approximately a factor of two (2). The incorporation of the thicker dielectric storage mesh will allow at least twice a given charge to be stored with the same exposure conditions used for the present CORRELATRONs. Both of these changes will reduce the minimum light level required for satisfactory IVS performance and will also reduce the write and erase times of the IVS for the present range of operation. It should be noted that the present write time will be required to obtain satisfactory subsystem performance for say one-quarter of the present minimum illumination required for satisfactory performance, therefore, trade-offs in the IVS performance can be made in order to obtain acceptable overall system performance.

3.3 Mechanization Changes

3.3.1 Variable Amplitude Nutation

Incorporation of a variable amplitude nutation capability in the IVS will enable the system to select the appropriate nutation amplitude to maximize the sensor output for a given scene. This will maximize the system signal-to-noise ratio for a given scene and will allow the IVS to remain locked on a marginal scene for a longer period of time than is presently possible. The optimum nutation for a given scene is a function of the correlation function of that scene. The IVS circuitry will optimize the nutation amplitude based on the CORRELATRON output signal which is a function of the scene correlation function.

3.3.2 Variable Exposure Control

The incorporation of a variable write exposure control will improve the IVS performance for high illumination, low contrast scene inputs. This modification will allow the scene modulation enhancement capability inherent in the CORRELATRON to be used to the ultimate in obtaining satisfactory system performance under the aforementioned adverse operating conditions. Extensive changes to the present IVS electronics will be required to incorporate this change.

3.3.3 Magnetic Zoom

Changes in the line-of-sight while tracking a ground scene, produce significant scale changes in the live image with respect to the stored image. This scale change rapidly degrades the correlation function, as sensed by the CORRELATRON, at the larger tracking angles. The introduction of a magnetic zoom capability in the IVS will compensate for the scene scale changes and improve the system performance while tracking a ground scene. The magnetic zoom will be accomplished by electronically controlling the sensor magnetic focus field as a function of look angle.

4.0 SPECIFICATION REVIEW

Following are the GAC comments on the specification EC-701A, Rev. 6, Engineering Critical Component Specification Performance/Design and Product Configuration Requirements for Image Velocity Sensor, 4 June 1968. Every numbered section is commented on. The comment "comply" indicates that GAC considers the requirement reasonable and that the requirement can be satisfied by the IVS. This does not mean to imply that there are no technical problems in complying to the requirement or that the present design necessarily satisfies the requirement.

1.0 Scope - Comply

2.1 Applicable Documents

(1) EC1602 High Frequency A/D Converter

This document was not included in the bid package, however, the following information was forwarded and taken into consideration in preparing the proposal.

1. A reference voltage of +5 VDC $\pm$1% to be supplied by analog source at 10 ma. Output impedance to equal to or less than 0.1 ohms.

2. Input power - provided by the analog data source

+4 VDC $\pm$5%	0.7W
+12 VDC $\pm$5%	0.15W
-12 VDC $\pm$5%	0.15W

3. Size - To be less than 1.5" x 3" x 4"

4. Weight - Shall not exceed 1 pound.

(2) DP1690A AN1 through 3 — Electromagnetic Compatibility Requirements for Equipments and Subsystems, Specification of

This document was not forwarded with the bid package and only AN1 and 2 were included. The GAC proposal is based on DP1690, Rev. 1 dated 11 November 1966 and AN1 and 2 to DP1690A.

(3) GE-711-03013 Rev. 1 — Space Envelope Available for IVS (M/A)

This drawing, revision A, was available at GAC for use in preparing the proposal. Significant comments on this drawing were forwarded to GE on 6 March 1968; M2197, Drawing Comments, and no reply has been received to date. The response to the aforementioned comments has a direct bearing on the IVS sensor design effort defined by WS701E, 27 May 1968. The proposal includes the effort to redesign the sensor to satisfy the space requirements of GE-711-03013.

(4) GE-711-03059 Electrical Schematic

Preliminary copies of 711-03059 were made available for review. There appears to be no problem with complying with this drawing when it is finalized, however, it should be noted that only five connectors are shown on the IVS electronics. The specification indicates there should be six connectors.

(5) TBD Space Envelope Available for IVS (A)

GAC has no information pertaining to this drawing, therefore, no consideration was given to its effect on the program in the proposal. It is assumed that all the required pertinent design information is contained in GE-711-03013.

3.0 <u>Requirements</u> (title)

3.1 <u>Performance</u> (title)

3.1.1 <u>Functional Characteristics</u> - Comply

3.1.1.1 <u>Primary Performance Characteristics</u> (title)

3.1.1.1.1 <u>Image Velocity Output Signals</u>

Comply, however, for the proposal GAC assumed that the 5 VDC reference voltage source was capable of supplying a 10 ma maximum current.

3.1.1.1.1.A <u>Dynamic Range</u> - Comply

3.1.1.1.1.B <u>Signal Linearity</u> - Comply

3.1.1.1.1.B.1 <u>Large Signal Region</u> - Comply

3.1.1.1.1.B.2 <u>Null Region</u> - Comply

3.1.1.1.1.C <u>IVS Noise and Bias</u> - Comply

3.1.1.1.1.C.1 <u>Noise Definition</u> - Comply

3.1.1.1.1.C.2 <u>Bias Definition</u> - Comply

3.1.1.1.1.C.3 <u>Requirements in Large Signal Region</u> - Comply

3.1.1.1.1.C.4 <u>Requirements in Null Region</u> - Comply

3.1.1.1.1.C.5 Determining Value of Periodic Noise Components - Comply

3.1.1.1.1.C.6 Determining Value of Random Noise Component - Comply

3.1.1.1.1.C.6.A Comply

3.1.1.1.1.C.6.B Comply

3.1.1.1.1.C.6.C Comply if the Figures 7-A through 7-E are in reality 5-A through 5-E of the specification.

3.1.1.1.1.C.6.D Comply

3.1.1.1.1.D Saturation

The IVS can comply with the 0.5 sec. recovery time, but can only partially comply with the 0.1 sec. recovery time. The lock-on time of the IVS varies from approximately 0.16 sec. to 0.3 sec., and is dependent on many factors, several of which are beyond the control of the IVS. The erase cycle is presently 0.065 sec., but may be reduced depending on the outcome of future trade-off studies. The write-cycle varies from approximately 0.01 to 0.015 sec., depending on scene brightness. There is an additional 0.080 sec., approximately, required for lock-on stabilization.

When a disable signal is not supplied to the IVS, but it is saturated, the IVS will continuously recycle until it locks-on. If the image velocity falls below the dynamic range of the IVS during the last 0.1 sec. of the cycle, the requirement for 0.1 sec. recovery will be met. If the image velocity falls below the dynamic range of the IVS during the rest of the lock-on cycle, the recovery time will be greater than 0.1 sec.

There will also be times when the IVS will lock-on for image velocities above 0.3 in/sec. If the tracking-mirror can respond fast enough to prevent the live image from reaching the edge of the stored image, the recovery time of 0.1 sec. can be achieved.

Presently, model improvements to the CORRELATRON are under investigation which will probably significantly reduce the erase and write times. There is a good possibility that these changes and some circuitry changes to reduce the settling time will allow the 0.1 sec. recovery time to be satisfied. The CORRELATRON improvement program should be complete within the next three months.

3.1.1.1.1.E Frequency Response

The IVS frequency response is related to the output power spectral density (PSD) requirement. Each of the requirements for frequency response and PSD can be satisfied independently, however, trade-offs between these two areas will probably be required in order to obtain satisfactory system performance. Close collaboration between GE and GAC engineers will be required to obtain satisfactory trade-offs related to these two areas.

3.1.1.1.2 Lock-On Signal - Comply

3.1.1.1.3 Operational Readiness Signal

It is felt that GAC can comply with this requirement, however, close coordination with GE engineering will be required in order to arrive at a mechanization which will be approved by GE.

3.1.1.1.4 Diagnostic Monitoring Signals - Comply

3.1.1.1.5 Sub-threshold Irradiance Signal

Comply, however, when the threshold energy spectrum defined in this section is convolved with the CORRELATRON photocathode response of the IVS, the resulting cathode current is greater than the current resulting from the use of curve 2 of Figure 11.

3.1.1.2 Secondary Performance Characteristics - Comply

3.1.2 Operability (title)

3.1.2.1 Reliability

GAC can comply with the 10,000 hour MTBF requirement exclusive of the CFE A/D Converter. It is assumed that the reliability of the converter will be a GE responsibility and the MTBF will be compatible with the IVS requirements.

3.1.2.2 Maintainability - Comply

3.1.2.2.1 Maintenance and Repair Cycles - Comply

3.1.2.2.2 Service and Access - Comply

3.1.2.3 Useful Life - Comply

3.1.2.4 Environmental - Comply

A clarification of the orientation of the electronics assembly with respect to the vehicle coordinate axes shown in GE 711-03013, Rev. 1 is desired so a rigorous dynamic load and stress analysis can be made.

3.1.2.4.1 Steady State Load Factors (N) (title)

3.1.2.4.1.1 Head - Comply

3.1.2.4.1.2 Electronics Box - Comply

3.1.2.4.2 Dynamic Environment (title)

3.1.2.4.2.1 Acceleration - Comply

3.1.2.4.2.2 Vibration - Comply

3.1.2.4.3 Pressure - Comply

3.1.2.5 Transportability - Comply

3.1.2.6 Human Performance - Not Applicable

3.1.2.7 Safety - Comply

3.1.2.7.1 Flight Safety - Comply

3.1.2.7.2 Ground Safety - Comply

3.1.2.7.3 Nuclear Safety - Not Applicable

3.1.2.7.4 Personnel Safety - Comply

3.1.2.7.5 Explosive and/or Ordnance Safety - Not Applicable

3.2 Component Definition (title)

3.2.1 Interface Requirements - Comply

3.2.1.1 Schematic Arrangement (title)

3.2.1.1.A Mechanical - see comments under 2.1 (5)

3.2.1.1.B Electrical - see comments under 2.1 (4)

3.2.1.2 Detailed Interface Definition (title)

3.2.1.2.1 Input Power Interface - Comply

3.2.1.2.1.1 Normal Conditions (title)

3.2.1.2.1.1.A Operating Voltage - Comply

3.2.1.2.1.1.B Ripple - Comply

3.2.1.2.1.1.C Transient Level and Duration - Comply

3.2.1.2.1.1.D Ripple and Transients - Comply

3.2.1.2.1.1.E Transient Energy Content - Comply

3.2.1.2.1.1.F Power Dissipation

Comply, except that no allowance is made in this section for the power supply inefficiencies or additional circuitry power requirements resulting from the incorporation of the CFE A/D Converter. The maximum average power requirement should be changed to 28 watts for the input voltage and operating times specified.

3.2.1.2.1.2 Abnormal Conditions (title)

3.2.1.2.1.2.A Applied Voltage - Comply

3.2.1.2.1.2.B Power Interrupt - Comply

3.2.1.2.2 Signal Interface (title)

3.2.1.2.2.1 A/D Converter

GAC feels that the requirements of this section can be complied with. However, further definition of the mechanical, structural, thermal and electronic requirements of the converter are required. Also see comments under 2.1 (1).

3.2.1.2.2.2 Telemetry Multiplexer - Comply

3.2.1.2.2.3 Monitor and Alarm Subsystem - Comply

3.2.1.2.3 Mechanical Interface (title)

3.2.1.2.3.1 Mounting

Compliance with the requirements of this section is contingent upon the GE drawing - TBD - not changing the clearance within the adapter used by the IVS or the sensor mounting arrangement as defined on GE drawing 711-03013. The comments under 2.1 (3) & (5) are also pertinent to this section.

3.2.1.2.3.2 Space Envelopes

GAC can comply with the sensor space allocation defined in GE 711-03013 although it requires a redesign of the Part O configuration, see comments under 2.1 (3).

Compliance with the electronics space allocation defined in EC-701A, Rev. 6 can be attained. However, compliance cannot be attained with the 711-03013 drawing space allocation with the A/D converter incorporated. It is assumed that the 711-03013 drawing will be revised to reflect the space allocation of EC-701A, Rev. 6. Figure 4-1 shows the GAC interpretation of the maximum allowable size for the electronics enclosure.

3.2.1.2.3.3 Weight

GAC can comply with the maximum weight allowed for the sensor but cannot comply with the IVS total weight of 23 pounds maximum. The estimated system weight is 25.6 pounds based on the new requirements of incorporating the CFE A/D converter, providing three (3) additional connectors on the electronics and providing the associated additional support structure, mounting hardware and wiring. The weight estimate will have to be adjusted when the GE drawing 711-03059 and the GE specification EC1602 are available for review and evaluation.

3.2.1.2.3.4 Alignment

GAC feels that compliance with the requirements of this section can be attained, however, the comments under 3.2.1.2.3.1 apply.

3.2.1.2.4 Optical Interface (title)

3.2.1.2.4.1 Optical Alignment - see comments under 3.2.1.2.3.4

3.2.1.2.4.2 Characteristics of IVS Input Images - Comply

3.2.1.2.4.2.A Image Format - Comply

3.2.1.2.4.2.B Image Dynamic Effects - Comply

3.2.1.2.4.2.C Location of IVS Image Plane - Comply

3.2.1.2.4.2.D Average Irradiance in IVS Image - Comply

3.2.1.2.4.2.E Abnormally High Image Irradiance

GAC can comply with the requirements of this section providing the IVS does not have to perform to the requirements of the specification EC-701A, Rev. 6 during the periods of exposure.

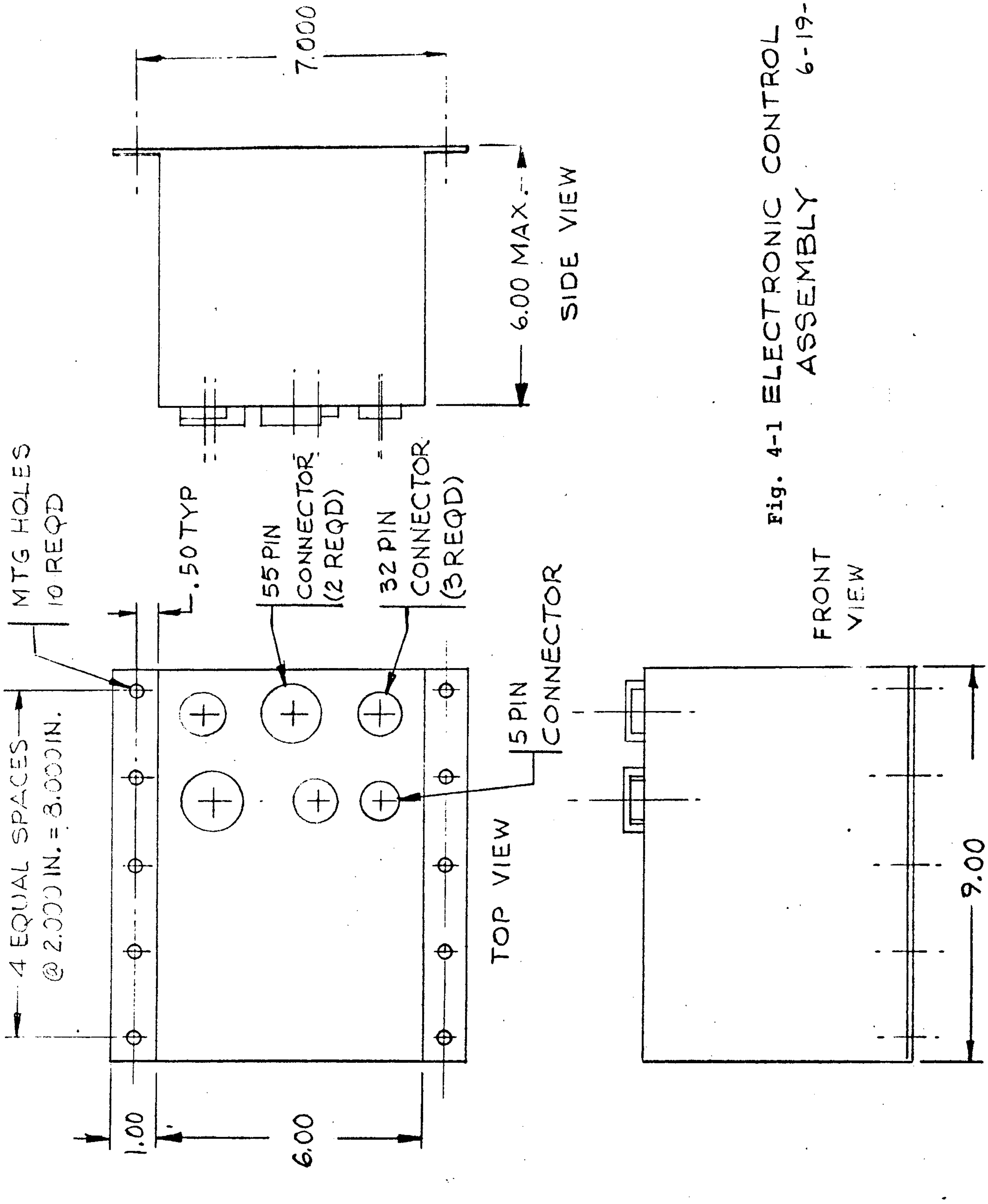

Fig. 4-1 ELECTRONIC CONTROL ASSEMBLY 6-19-68

3.2.1.2.4.2.F Image Contrast and Spatial Frequency Distribution

Comment on this section must be reserved until the - TBD - items are defined.

3.2.1.2.4.2.G Uniformity of Image Irradiance - Comply

3.2.1.2.4.2.H Polarization - Comply

3.2.1.2.5 Thermal Interface (title)

3.2.1.2.5.1 Electronics Box

GAC can comply with the requirements of this section providing the Console Envelope Reference Drawing - TBD - does not change any of the presently stated requirements.

3.2.1.2.5.2 Sensor Head

The power dissipation within the sensor shall be held to a minimum but the design goal of 3 watts maximum cannot be satisfied. Presently the estimated sensor power dissipation is nine (9) watts. Some reduction in total sensor power dissipation is possible but certain trade-offs will have to be agreed upon during the course of the program. Also, it is assumed that section 4.4.3.2-A of DR1100, to be defined, will only change the temperature monitoring interval which should have no effect on the proposal.

3.2.2 Component Identification - Not Applicable

3.3 Design and Construction (title)

3.3.1 General Design Features (title)

3.3.1.1 Dimensions

See comments under 3.2.1.2.3.2

3.3.1.2 Weight

See comments under 3.2.1.2.3.3 (specification ref. error)

3.3.1.3 Wiring - Comply

3.3.1.3.1 Cabling and Connectors - Comply

3.3.1.4 Dielectric Strength and Insulation Resistance

Compliance with the requirements of this section is based on the assumption that the testing of the dielectric strength and insulation resistance is performed in accordance with section 4.1.3.4.1.1 which allows for protecting certain electronic devices.

3.3.1.5 Emissivity - Comply

3.3.1.6 Colors - Comply

3.3.1.7 Cleanliness - Comply, however, GAC assumes that since both of the IVS packages are hermetically sealed no special cleaning is required for any parts installed within the packages. Also, it is assumed that no special cleaning of the external surfaces is required by GAC, however, the external surfaces must be such that they can be cleaned satisfactorily. No special considerations were given to the cleaning of the components in preparing the proposal.

3.3.1.8 Grounding - Comply

3.3.1.9 Hermetic Sealing

The maximum leak rate of 10^{-8} atmospheric cubic centimeters per second is difficult to achieve on the packages of the IVS. It is recommended that a design requirement of the maximum leak rate be 10^{-6} atmospheric cubic centimeters per second with a design objective of 10^{-8} atmospheric cubic centimeters per second.

3.3.1.9.1 Component Seal - Comply

3.3.2 Selection of Specifications and Standards - Comply

3.3.3 Material, Parts and Processes - Comply

3.3.4 Standard and Commercial Parts - Comply

3.3.5 Moisture and Fungus Resistance - Comply

3.3.6 Corrosion of Metal Parts (title)

3.3.6.1 Electrolytic Corrosion - Comply

3.3.6.2 Stress Corrosion - Comply

3.3.6.3 Protective Treatment - Comply

3.3.7 Interchangeability and Replacement - Comply

3.3.8 Workmanship - Comply

3.3.9 Electromagnetic Interference

GAC feels compliance with the requirements of this section can be attained but there is a potential problem area involving the optical window of the sensor. It is assumed that deviations will be granted, on a closely controlled and selective basis, to the electromagnetic interference requirements if it becomes apparent that these requirements cannot be met because of the use of the optical window in the sensor. The application of coatings or other types of EMI suppression to this window would effect light transmission and seriously degrade the low light level performance of the device.

3.3.10 Identification and Marking - Comply

3.3.11 Storage - Comply

3.3.12 Vibration (title)

3.3.12.1 Sensor Generated Vibration - Comply

3.3.12.2 Resonance - Comply

3.3.12.3 Sensor Generated Noise (Acoustic) - Comply

4.0 Quality-Assurance Provisions (title)

4.1 Category I Test (title)

4.1.1 Engineering Test and Evaluation - Comply

4.1.2 Preliminary Qualification Tests - Not Applicable

4.1.3 Formal Qualification Tests - Comply

4.1.3.1 Inspection - Comply

4.1.3.2 Analysis - Comply

4.1.3.3 Demonstrations - Not Applicable

4.1.3.4 Tests - Comply

4.1.3.4.1 Preliminary Tests (title)

4.1.3.4.1.1 Dielectric Strength and Insulation Resistance - Comply

4.1.3.4.1.2 Continuity-Test - Comply

4.1.3.4.1.3 Performance Test - Comply

4.1.3.4.1.4 Interface Test - Comply

4.1.3.4.1.5 Corona and Arcing Test - Comply

4.1.3.4.2 Operability-Assurance Test - Comply

4.1.3.4.3 Qualification Environmental Tests

Comply with the understanding that for

(1) item B, the higher curve of Figure 8 of EC-701A, Rev. 6 defines the test requirements and paragraph 4.4.3.5 of DR1100 defines the test procedure.

(2) item J, paragraph 4.2.4 of DP1690 accepts the use of the interference meter, Fairchild EMC-10, in performing the conducted interference test. This meter has a bandwidth of 50 Hz while DP1690 specifies the measurement should be made with a 60 Hz bandwidth. Therefore, a deviation is requested to make the measurement with a 50 Hz bandwidth. Also, there is some doubt about the availability of the McDonnel Electronics Equipment Model 35G001 transient generator. An equivalent unit which satisfies the requirements of DP1690 has not been found. Deviation is requested for performing the conducted transient test with a pulse width of 200 microseconds if a suitable generator cannot be obtained.

(3) item M is not applicable.

(4) item N applies but will be defined later.

4.1.4 Reliability Test and Analysis - Comply

4.1.5 Engineering Critical Part Qualification - Not Applicable

4.2 Category II Test Program - Not Applicable

6.0 Notes - Not Applicable

10.0 Appendix - Not Applicable

Figures - Comply

5.0 ANALYSIS AND TRADE-OFFS

5.1 General

The proposed program includes a study effort which will provide analysis of the IVS performance and evaluate trade-offs to be made involving the IVS design. Proposed studies that directly support the IVS design effort are the following:

(1) Center of Power Effects,
(2) Illumination Spectrum Effects,
(3) Output Power Spectral Density Investigation,
(4) Dynamic Response Investigations.

Studies which involve the evaluation of trade-offs in the IVS design are the following:

(1) Dynamic Range vs. Accuracy,
(2) Dynamic Response vs. Accuracy,
(3) Linearity vs. Accuracy,
(4) Power vs. Weight vs. Accuracy,
(5) High and Low Frequency Time Share of Light with the Visual Optics vs. Accuracy,
(6) Accuracy vs. Image Luminance.

An Error Analysis study will be performed on the IVS. Also, Dynamic Performance Model studies and a Cloud Obscuration study will be conducted.

5.2 Design Effort Support Studies

5.2.1 Center of Power Effects

A preliminary effort on the Center of Power Effects study has been started on the Part O program. Basic concepts and a basic understanding of the effects of the image center of power effects on the IVS performance as a function of look angle will be gained during the Part O program. Refinements of the basic concepts and a complete evaluation of the image center of power effects on the IVS determination of the velocity at the center of format remain to be completed during the proposed program. This study will involve analytical and experimental investigations of the effects of various scenes, with known centers of power, on the IVS performance.

5.2.2 Illumination Spectrum Effects

The Illumination Spectrum Effects study will involve experimental and analytical evaluations in order to determine the effects of the revised illumination spectrum defined in EC-701A, Rev. 6 on the IVS performance. This study will include the determination of the effects of different atmospheric conditions as well as various sun angle and look angle effects on the IVS performance with respect to the illumination spectrum.

5.2.3 Output Power Spectral Density Investigation

This investigation will analytically and experimentally evaluate the IVS output power spectral density with respect to the revised requirements of EC-701A, Rev. 6. The task is a continuation of the one started in the Part O program. The effort on the proposed program in this area is to update the PSD computer program to be compatible with the revised specification and evaluate the updated IVS design when it is available. Collaboration with GE engineering will be required to properly update the computer program.

5.2.4 Dynamic Response Investigation

The Dynamic Response Investigation effort consists of developing the analytical transfer functions for the various functional blocks within the IVS. A comparison of the theoretical block diagram with experimentally obtained data will be made in order to verify the theoretical work. The results of this study will aid in understanding and possibly improving the IVS system.

5.3 Trade-Off Studies

5.3.1 Dynamic Range vs. Accuracy

The Dynamic Range vs. Accuracy study will be primarily interested in defining and evaluating the trade-offs involved in changing the IVS dynamic range to improve the accuracy of the system. Revised requirements for scaling and hence the dynamic range of the IVS appear in EC-701A, Rev. 6. These requirements will be evaluated and then the trade-off portion of the study will follow.

5.3.2 Dynamic Response vs. Accuracy

This study will evaluate the revised requirements of EC-701A, Rev. 6 with regard to the IVS response and identify and evaluate the trade-offs involved in improving the system accuracy by modifying the IVS dynamic response. Experimental support for this study will be provided by the operation of an IVS breadboard on the GAC simulator.

5.3.3 Linearity vs. Accuracy

The trade-offs involved in improving the IVS accuracy at the expense of linearity will be identified and evaluated during the course of this study. Experimental evaluations of the possible trade-offs will be included.

5.3.4 Power vs. Weight vs. Accuracy

A trade-off study will be conducted to identify and evaluate methods of improving the IVS accuracy by possible increases in subsystem weight and power. Experimental evaluations of the recommended trade-offs will be made, as well as analytical evaluations.

5.3.5 High and Low Frequency Time Share of Light with the Visual Optics vs. Accuracy

The improvement in system accuracy will be investigated with respect to obtaining a higher input illumination level by time sharing the light made available to the visual optics. Providing additional light during periods of low light level operation clearly will improve the IVS performance but possibly this light could be provided at a high frequency rate which would not appreciably deteriorate the IVS or the observers image and improved performance could be obtained without undue compromise of the observer. A complete analytical and experimental investigation of this mode of operation is planned.

NOT NEEDED

BECAUSE ... PRIME MODE

5.3.6 Accuracy vs. Image Luminance

The effects of variations in scene luminance on IVS accuracy will be investigated both analytically and experimentally. Both uniform and non-uniform luminance variations will be considered involving various atmospheric conditions and sun and look angles.

5.4 Error Analysis

An error analysis of the IVS will be conducted encompassing all error contributors from the input imagery to the output signals. Experimental verification of the analytical study will be made where practical.

5.5 Dynamic Performance Model Studies

The objective of this analytical and experimental study will be to complete the development of a math model of the BETA Sensor. The model will be implemented in the form of a digital program for the IBM 360 (S40) computer, in order to provide an efficient and flexible capability to predict the output signal performance characteristics as a function of changes in either the input image parameters or in the sensor internal component parameters.

During the Part O program, a separate study was performed to develop the techniques required for mathematically specifying the input optical image. This preliminary effort primarily concerned the evaluation of computer generated synthetic images, to identify the scene parameters which significantly influence the sensor correlation response. Generally, these special images were mathematically specified by a tabulation of the transmissivity and color at each individual point across the entire format.

Also during the Part O program, a separate study was performed to develop the techniques required for mathematically specifying the performance of the BETA Sensor tube. Emphasis was restricted to this particular component of the sensor, since the tube operation represents a complex inter-relationship between many individual physical responses. This preliminary effort identified the responses that were significant to the model, and defined appropriate mathematical expressions. Generally, the tube model was formulated on the basis of synthetic input imagery that could be specified on a point-by-point basis.

During the proposed study effort, these two investigations will be continued, but they will be integrated into a single program to develop a sensor math model. This reflects the need during this phase to provide a marriage between the response function of the sensor and the excitation function of the input image. Accordingly, the program will primarily concern an effort to specify complex actual input imagery in a mathematical form that can be accepted by the sensor model, and to adapt the sensor model to insure full accommodation of the input stimulus. To achieve a manageable model, an image specification technique other than a point-by-point tabulation will be required; i.e., one which can combine all the significant image characteristics into a relatively simple mathematical expression.

To develop such an expression, both analytical and experimental studies will be performed. The laboratory effort will include the scanning of image samples with a microdensitometer to determine the spot size (resolution) and the scanning patterns (% coverage) that are required for adequate specification. An attempt will be made to find suitable combinations wherein the data obtained from relatively few scans, or from averages obtained by non-spot apertures (e.g., slits), is shown to be sufficient. Tests will also be performed with coherent and non-coherent optical processors to determine whether data extracted from the frequency transform plane or from the autocorrelation response will be sufficient. It is likely that data obtained from a reasonable combination of these various sources will be required for a comprehensive specification of the image characteristics, and that machine processing of this data will be required to generate the corresponding mathematical expression for the model input stimulus.

The analytical effort concerning image specification will provide the equipment and measurement parameters to be examined experimentally, based on the image characteristics which are known to influence the correlation response. This effort will also provide the programming necessary to process the resulting data. The effort will not include a specific effort to establish the nominal physical characteristics of terrain imagery received at a spaceborne sensor. The effort will, however, include a study to determine if these nominal characteristics, if available, could be used to adequately specify the model input stimulus. Such summary characteristics are spatial frequency distribution, spectral distribution, etc. will be considered.

The image specification study will be closely coordinated with the development of the sensor model, to insure that the expressions for the input stimulus are mechanized in a form that can be readily accommodated by the model. Likewise, the prediction performance that results from trial exercising of the model will be evaluated to identify deficiencies in the image specification and to conceive necessary improvements or allowable simplifications.

The effort to develop a mathematical model of the BETA Sensor will, as previously mentioned, include modification of the model form in order to accept input expressions that fully describe complex actual terrain images. In addition to this, the study will include the general improvement and refinement of the expressions used to describe the individual physical responses and their inter-actions within the sensor tube. The model will also be expanded to include the electronics external to the tube, as required to fully describe the output signal characteristics under null and dynamic conditions. Expressions for noise and non-linear responses will also be included.

During the proposed program, a significant effort will be expended to program the 360 computer as defined by the math model, and then to exercise the computer in such a manner as to isolate the deficiencies. For this evaluation, actual sensor output signal characteristics will be generated from comparison with the model results by performing appropriate tests with the Princess Sensor and Laboratory Simulator.

5.6 Cloud Obscuration Study

The objective of this analytical and experimental study will be to determine how specific cloud and terrain parameters influence the intended performance of the BETA Sensor, and to determine the characteristics of sensor signals that are selected as indicative of cloud obscuration. This will be a logical continuation of a corresponding effort initiated during the Part O program. As such, the proposed effort will primarily concern the refinement of image parameters, obscuration simulation, test procedures, and data evaluation.

The study will include a continued evaluation of engineering data concerning typical cloud characteristics that is available from this and other programs. This information will be used to develop obscuration simulation techniques which provide more realistic parameters. The servo-driven image fixture, the BETA Sensor, and the Laboratory Simulator will be used to experimentally determine which obscuration models prohibit "in-spec" performance when used in conjunction with a variety of typical terrain scenes. This data will be compiled in a form to show the probability of successful performance as a function of the type and degree of obscuration.

Also as part of these tests, selected signal points within the sensor will be monitored. This data will be evaluated to determine the nominal characteristics of these signals as a function of the obscuration parameters. These characteristics will be analyzed, in turn, to develop computer processing techniques capable of automatically indicating the type and degree of obscuration. Analysis or trial computer runs will be performed to identify obscuration conditions which can result in ambiguous indications, or in errors of commission or omission.

Refinements in signal measurement techniques and/or alternate processing techniques will be evaluated, as required to minimize these deficiencies.

At the conclusion of the proposed program, it is anticipated that the obscuration conditions which can prohibit satisfactory performance of the BETA Sensor will be specified. Likewise, the signal measurement and signal processing techniques required for an automatic indication of obscuration conditions will be defined in sufficient detail to adequately determine the influence of this capability on the mission effectiveness.

6.0 DESIGN APPROACH

6.1 General Description

The IVS system is composed of two subassemblies, a sensor and an electronics control assembly and one interconnecting cable. A test cable is delivered with each IVS. However, GAC must only define the requirements of the interconnecting cable in the final installation.

The sensor is a hermetically sealed unit containing the CORRELATRON, focus and deflection coils, erase lights and the sensor electronics. Hermetic sealing of this unit is required to protect the CORRELATRON, which is a vacuum tube with a glass envelope, from the helium environment. It has been demonstrated that helium gas readily penetrates the glass envelope of the CORRELATRON and reduces the vacuum inside the tube to an unacceptable level in a relatively short period of time. It has also been demonstrated, that an enclosure approximating the sensor housing size and construction can adequately protect the CORRELATRON from the helium environment for the proposed application. The sensor will be purged and filled with 0.5 atmospheres of dry nitrogen after the seals have been made. A pressure sensor will be installed to allow for the evaluation of the seal integrity throughout the life of the unit.

The sensor electronics consists of six individual potted modules including the high voltage supply, high voltage control and focus current regulator. It should be noted that all of the high voltage connections are contained within the hermetically sealed sensor package. This is a primary consideration with respect to personnel safety.

The electronics control assembly is also a hermetically sealed assembly, filled with 0.5 atmospheres of dry nitrogen and contains a pressure sensor. Multilayer board construction is used for mounting the integrated circuits and associated discrete components. Components with high power dissipations are mounted on heat sinks with good thermal conducting paths to base. The unit will be designed to operate mounted on a heat sink. The case will be painted to give a thermal emissivity of 0.85 or greater. All heavy components are mounted near the base for mechanical stress considerations. The CFE A/D converter will also be contained in this assembly. All electrical connections to the electronics assembly are made through six hermetically sealed connectors mounted on the surface opposite the mounting surface.

6.2 Block Diagram and Theory of Operation

Figure 6-1 is a block diagram of the IVS system. Following is a discussion of the operation of the IVS system.

In order to obtain image rate information the IVS uses the CORRELATRON in a closed loop system. To function properly, the CORRELATRON requires three modes of operation:

(a) A "write" mode, wherein the initial image position is stored as a two-dimension charge pattern, and during which the IVS output is inhibited.

(b) A "read" mode, wherein correlation of the input image and the previously stored reference is performed, and during which the sensor output is enabled.

(c) An "erase" mode, wherein the previously stored reference charge pattern is removed from the storage mesh, and during which the sensor output is inhibited.

During the write mode, an optical image is stored within the CORRELATRON by electron secondary emission of the storage mesh.

During the read mode, a switching sequence is enabled to the tube elements to reduce the electron velocity so a non-destruct readout can be performed. Thus, for the single write sequence many non-destructive comparisons can be made before signal degradation occurs and a new write sequence is required. Before a new image is stored an erase signal actuates the "erase lights" and biases the CORRELATRON so that the storage mesh, stored image, is flooded with a uniform electron bundle and a "clean slate" is prepared to receive the write signal.

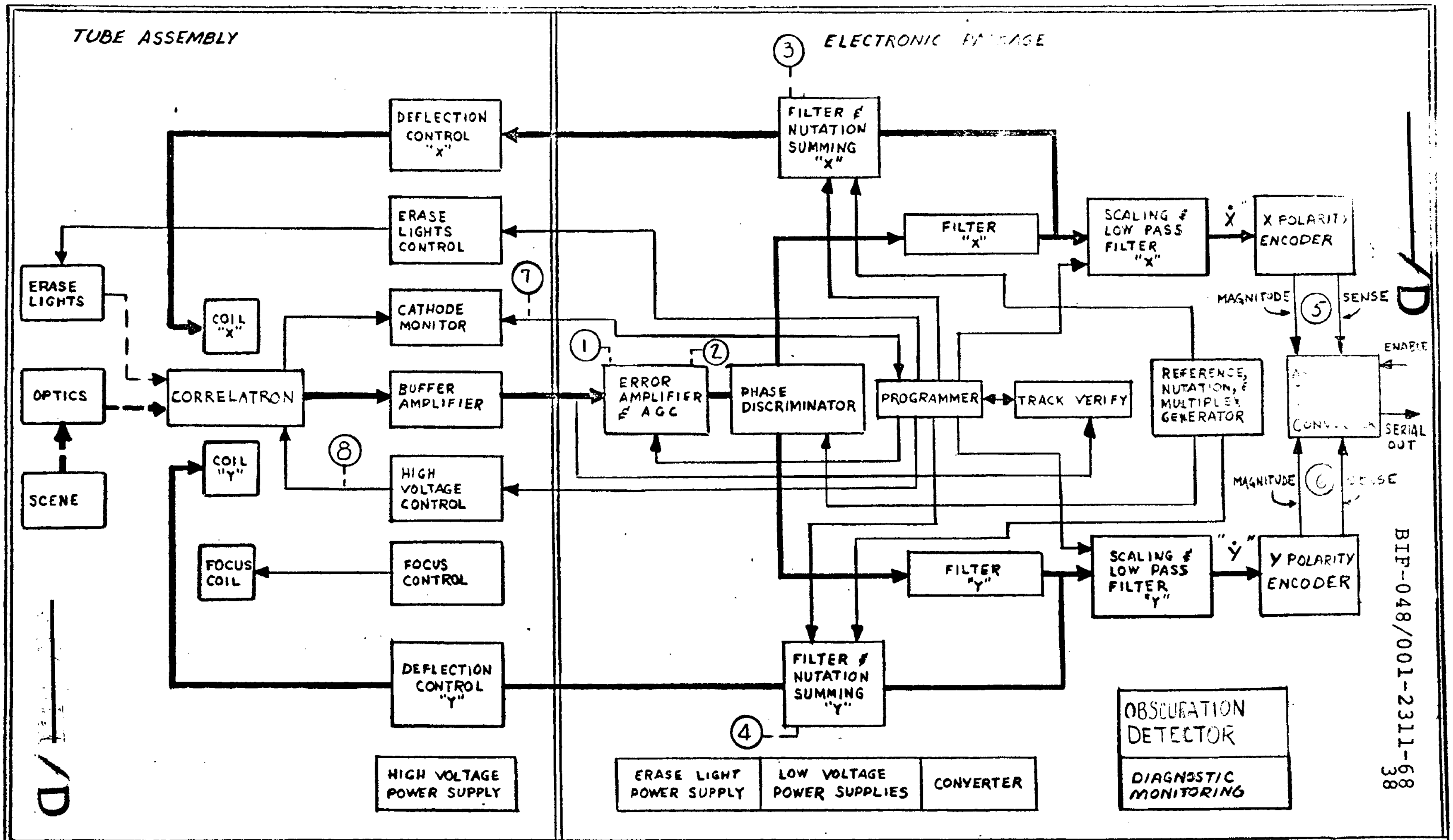

Figure 6-1 Block Diagram of the IVS System

The data stored in the CORRELATRON is fixed on an x-y plane. The incoming optical image produces an electron bundle within the CORRELATRON which is nutated a small amount by field modulation in the coils around the CORRELATRON and an area match yields a maximum output when the input and stored images are superimposed. Closed loop characteristics of the IVS maintain the image superposition as the subject moves by displacing the field around the CORRELATRON and deflecting the image signal.

The input is nutated in x and y by a one kilohertz sine wave. The x deflection is activated for one cycle, while the y is blanked and then the y is activated for one cycle while the x is blanked. The output data is thus a complex, multiplexed signal which will be synchronously demodulated to separate x and y. During a closed loop match condition, this signal appears as a full wave rectified sine wave. Under normal conditions this signal may vary from one millivolt peak-to-peak to 150 millivolts peak-to-peak depending on the image and it is riding on a 2,000 VDC level.

The "buffer amplifier" is an AC coupled high impedance amplifier and converts the signal from the high voltage, current source, CORRELATRON to a ground level, low output impedance source.

The low level "buffer amplifier" signal is amplified and AGC'd to provide a three volt peak-to-peak replica of the error signal without distortion or phase shift. To accomplish this, the three error amplifiers provide a common bandpass well in excess of an order of magnitude above and below the 1K Hz full wave rectified sine wave. Since the signals are multiplexed, only the single channel of gain is required. However, to properly AGC the separate x and y data there are two separate AGC amplifiers that are multiplexed synchronously into the feedback loop for the three stages. Each of the two AGC circuits employ a single lead-single lag network that is tuned to the 2K Hz ripple of the match signal to control the AGC operation.

The fixed amplitude wave is then passed through the phase discriminator which reconstructs the match signal in a manner to obtain the least DC output for the best match. When the CORRELATRON senses drift of the input image by distortion of the full wave rectified signals "form factor", the phase discriminator determines magnitude and direction to correct the loop, and maintain the proper form factor.

The correction signal, still multiplexed, is now separated by synchronous demodulation and sent to separate x and y filters for processing. Each filter is designed to produce a double break at 34 Hz. The signal separation is accomplished prior to these filters to avoid smearing the x and y data.

Each of the nutation summing amplifiers has a DC input which is controlled by the output of an integrator. The input to each of the two integrators is the output from one of the 34 Hz filters. By summing the nutation signal and the integrator output, the incoming image is deflected across the stored image maintaining the match signal. When the incoming image is displaced away from the centroid far enough that the integrator cannot force the deflection to match, then the "saturation limiters" force an erase-rewrite mode. The new write will start with the stored image of the CORRELATRON centered and both integrators zeroed.

To maintain the closed loop condition, the small nutation must be maintained to generate a match signal. To maintain "lock-on" the integrators must slew to properly energize the coils, and deflect the incoming image from its present position on the CORRELATRON photocathode face to its originally stored position. The position saturation monitors control the limit of the slewing for both x and y in both directions. A verification circuit monitors the match signal from the third error amplifier to determine the condition of operation after write. The verify circuit compares the amount of 2K Hz ripple to the amount of 1K Hz in the error signal.

The closed loop response maintains the optimum position match between the drifted image, somewhere on the CORRELATRON photocathode, to the stored image. The integrator that maintains "position " must, by definition, have "rate" as its input. Rate inputs to the integrators, IVS output rates, are filtered by a 3.5 Hz filter and this relative DC output is scaled to provide the proper range of voltages for the input image rates encountered. This output is converted to provide a zero to plus five volt output with a polarity bit for negative excursions. The purpose of this is to provide a bounded zero volt to plus five volt input to the Analog to Digital converter. The polarity bit will be used with the digital readout for negative excursions.

The operating sequence is implemented in the following manner:

1. A six second warm-up interlock is enabled when power is applied.

2. At the end of warm-up, and if the input scene illumination level is in excess of minimum requirements, the system steps into the "standby" mode which indicates operational readiness.

3. If a "track command" is available the system will step from standby without delay. Without a "track command" it will remain in the operational ready or "standby mode". Given the three primary "initial conditions": the six second warm-up, satisfactory illumination and a track command the system will initiate an initial erase to prepare the CORRELATRON and establish all initial conditions in the operating sequence.

4. The next sequence step is a "write" cycle which is dynamic with light intensity such that a low light causes a longer write period. The maximum write time is clocked to force an erase and rewrite if the write time exceeds some predetermined value.

5. When the write mode is satisfied, the CORRELATRON is switched to the "read mode". For about the first 80 milliseconds of the read mode, a stabilization and verification period is established. After approximately

40 milliseconds of stabilization, the 3.5 cycle filter inputs are enabled to permit their initializing before being placed "on line". The verification circuit is also enabled to permit an evaluation of the match. The "verification" consists of comparing the 2K Hz "match" signal to the 1K Hz "lost" signal. At the end of the stabilization and verification period, after switching to "match", the logic "enables" the output of the verification circuit and "enables" the position and saturation monitors. Two clock pulses at a 2K Hz clock rate are permitted before the "lock-on" signal and output data are released to permit verify or saturation to operate prior to "lock-on".

6. "Lock-on" consists of passing the verify test without limiting on the position or deflection coil drives. Otherwise an erase mode is activated and a new cycle begun. A rate saturation is read out but does not force a recycle. During "lock-on" the verification makes a continuous monitor of the quality of the match. Once in the "lock-on" mode the system will stabilize and "match" the image until the deflection coils reach a limit or the verification indicates a degraded match signal. The system will cycle and erase and rewrite continuously until the "track command" is removed or low input illumination is encountered.

7. There are two operational modes that will stop the system with track command on, one is low input illumination, the second loss of power.

   (a) If low illumination is encountered a low light indicator is activated to produce an IVS output indication and the system continues in lock-on until the next recycle. Recycle can be initiated by either the track verify circuit or an input command to the IVS. At that point the IVS enters the erase mode and erases and stops the clock.

When light again becomes available and if the track command is still on, it will erase again to clear the system and then continue cycling.

(b) If power is dropped for less than one second the system will not go through warm-up. It will erase as the first step when power comes back on. If power loss is longer in duration, the system will "warm-up" for two seconds, erase and then continue operation.

6.3 Equipment Characteristics

6.3.1 Size

Figures 4-1 and 1 show the outline dimensions of the proposed electronics control assembly and sensor of the IVS. The sensor length must be reduced by about 0.25 inches in order to comply with the space allocation of GE drawing 711-03013.

6.3.2 Weight

6.3.2.1 IVS System

The estimated weight of the IVS system is approximately 25.6 pounds. This exceeds the specified maximum weight by 2.6 pounds. The increased weight is required to accommodate the new requirements for mounting the CFE A/D converter, increasing the electronics assembly package size for the converter, adding three additional connectors on the electronics assembly and providing the additional wiring needed.

6.3.2.2 Sensor Weight Breakdown

Following is a tabulation of the measured component weights for the Part O sensor.

Part Name	Measured Weight (pounds)
End Cap	0.31
Cover	0.30
Solder	0.01
Field Lens Lock Ring	0.03
Field Lens Assembly	0.32
Relay Lens Lock Ring	0.02
Relay Lens Assembly	0.23
Window Retaining Ring	0.03
Window	0.02
CORRELATRON Assembly	1.38
Coil and Light Assembly	4.47
Sensor Body	6.20
Connector Assembly	0.05
Exhaust Tube	0.03
Component Board Assembly	0.07
X&Y Deflection Control Assembly	0.14
2 KV Filter Assembly	0.25
Chopper and Rectifier	0.29
Terminal Board Assembly	0.08
Wiring	0.03
H.V. Component Assembly	0.26
Focus and Light Control	0.13
H.V. Control Assembly	0.14
Total	14.79

The required sensor weight of 14 pounds maximum can be met by some redesign primarily in the area of the sensor housing. This will be accomplished during the proposed program. No problem is anticipated in satisfying the sensor weight requirement.

6.3.2.3 Electronics Control Assembly Weight Breakdown

Following is a tabulation of the electronics control assembly component parts weights. Measured values are shown where possible and are indicated as such.

Part Name		Weight (pounds)	
Base Housing:	Part 0	1.80	(actual)
	Growth	1.35	(estimate)
Outer Case:	Part 0	0.20	(estimate)
	Growth	0.07	(estimate)
Cover Assembly:	Part 0	0.55	(actual)
	Growth	0.43	(estimate)
Connector Mounting Assembly:	Part 0	0.75	(actual)
	Growth	0.18	(actual)
Wire and Hardware	Part 0	0.10	(estimate)
	Growth	0.10	(estimate)
Toroid Mounting Assembly:	Part 0	1.57	(actual)
	Growth	0.50	(estimate)
CFE A/D Converter		1.00	(specified)
Shim		0.01	(estimate)
Spacer		0.01	(estimate)
A1 P.C. Assembly		0.46	(actual)
A2 P.C. Assembly		0.30	(estimate)
A3 P.C. Assembly		0.30	(estimate)
A4 P.C. Assembly		0.30	(estimate)
A5 P.C. Assembly		0.30	(estimate)
Ground Bus Assembly		0.03	(actual)
	Total	10.31	

Growth in the above table indicates the additional weight required to satisfy the revised requirements of EC-701A, Rev. 6. The total estimated increase in weight is 3.63 pounds including the CFE A/D converter specified weight of one pound. Taking into account the tabulated weights and allowing for growth during the IVS design phase, GAC feels a reasonable system weight requirement is 25.6 pounds maximum.

6.3.3 Power

6.3.3.1 IVS System

The total IVS system power estimate for the Part 0 unit is about 25.6 watts. Addition of the CFE A/D converter requires one additional watt. Taking into account the IVS power supply inefficiencies, 28 watts maximum appears to be a reasonable IVS power requirement for inclusion of the CFE A/D converter. Presently, the proposed system power estimate totals about 27.7 watts.

6.3.3.2 Sensor Power Breakdown

The following is a tabulation of the current estimate of the sensor average power for an operating duty cycle of 20 minutes on and 70 minutes off.

Circuit	Power (watts)
CORRELATRON	0.120
Buffer Amplifier	0.042
Deflection Control (X&Y)	1.310
Deflection Coil	0.049
Focus Coil	4.453
Erase Light Control	0.081
High Voltage Control	0.730
Erase Lamps and Ballast	0.080
Cathode Monitor	0.042
H-V Power Supply	0.550
Focus Control	1.485
Total	8.942

6.3.3.3 Electronics Control Assembly Power Breakdown

Following is a tabulation of the current power estimate for the electronics control assembly.

Circuit	Power (watts)
Error Amplifier and AGC	0.324
Phase Discriminator Filter & Feedback Filter (X&Y)	0.466
Output Filter, Polarity & Sense (X&Y)	0.300
Reference Nutation & Multiplex Generator	0.084
Programmer and Track Verify	6.190
Diagnostic Monitoring	0.336
Obscuration Detector	0.196
CFE A/D Converter	1.000
L-V Power Supply	9.850
Total	18.746

6.3.4 Reliability

The present MTBF estimate for the IVS is in excess of 11,000 hours. The additional requirements implied by the GE drawing 711-03059 will undoubtedly have an adverse effect upon the estimated MTBF. No allowance has been made for the added CFE A/D converter since this item is a GE responsibility.

All IVS drawings will be approved by Reliability as a normal release procedure on this program, although it is not a normal company policy. It is the opinion of GAC that reliability of the IVS is second in importance only to system performance. All incoming parts will be functionally tested, reliability tested on a lot sample basis and stored in a bonded area until required for fabrication of the IVS. Strict adherence to approved procedures will be enforced so the component reliability will not be degraded.

6.3.5 Diagnostic Monitoring Signals

The proposed IVS will provide the following analog output signals for monitoring the performance of the system.

1. Buffer Amplifier output
2. Error Amplifier output
3. X position
4. Y position
5. X velocity
6. Y velocity
7. Cathode current
8. Write voltage

These signals allow the IVS performance to be evaluated by providing an indication of the average input illumination (cathode current) and monitors several points in the forward path, the outputs and the feedback paths. Also, the write mode voltage pedestal is measured. Each of these signals are buffer isolated from the IVS primary signal components for reliability considerations and will be scaled to be compatible with the telemetry requirements. The diagnostic monitoring points are indicated on the IVS block diagram, Figure .

7.0 HIGH RISK TECHNICAL PROBLEMS AND PROPOSED SOLUTIONS

7.1 General

The following items are considered technical risk items on the proposed program. Each item is subsequently discussed in detail including the approach to be taken in minimizing the risk.

1. A/D converter incorporation
2. Saturation - 0.1 second recovery time
3. IVS frequency response vs. output power spectral density
4. Reliability
5. Power dissipation
6. Weight
7. Electromagnetic Interference

7.2 A/D Converter Incorporation

The following items concerning the CFE A/D converter are critical to the satisfactory completion of the proposed program.

1. Delivery to GAC
2. Thermal requirements
3. Physical characteristics

Following are the required dates for receipt of the CFE A/D converters at GAC to support the IVS program. One unit is required by each date indicated.

1968	1 Nov, 1 Dec
1969	1 Feb, 1 Mar, 1 Apr, 1 May, 15 May, 1 June, 15 June, 15 Sept
1970	1 Jan, 15 Jan, 15 Apr, 15 Aug, 15 Nov, 15 Dec
1971	15 Mar, 15 Apr

Spares will have to be provided in addition to the above required units to support the fabrication and repair phases of the program. The definition of the thermal requirements and the physical characteristics of the converter will be needed by 15 September 1968 to support the IVS design effort. Close coordination between GAC, GE, and the A/D converter vendor will be required in order to provide the aforementioned information and hardware to support the program schedule.

7.3 Saturation - 0.1 Second Recovery Time

Presently, the IVS cannot meet the 0.1 second recovery time under all operating conditions as discussed under section 3.1.1.1.D of the comments on the specification. CORRELATRON modifications (re. 3.2) and IVS electronic mechanization changes are presently under evaluation in the Part O program which will allow the IVS to more nearly satisfy the 0.1 second recovery time requirement. Coordination with GE engineering during the proposed program should give a better understanding of the performance of the system utilizing the IVS and satisfactory IVS performance of the IVS with regard to this requirement should result.

7.4 IVS Frequency Response Vs Output Power Spectral Density

The IVS performance will satisfy the requirements for frequency response and power spectral density of the output independently. However, certain trade-offs will be required in order for the system to satisfy both requirements simultaneously. Coordination with GE engineering, in evaluating the trade-offs when more IVS performance data is available, will enable the system to satisfactorily perform in the final application.

7.5 Reliability

The present IVS estimated MTBF is in excess of 11,000 hours. Addition of selected, redundant circuits will increase this number. However, the addition of the circuitry required by incorporating the A/D converter and GE drawing 711-03059 will have an adverse effect upon the MTBF. These effects will have to be evaluated when better circuit definition is available. Close collaboration between GE and GAC engineering should assure compliance with the MTBF requirement of 10,000 hours.

7.6 Power Dissipation

The present specification pertaining to the maximum IVS power dissipation makes no allowance for the required increases resulting from the addition of the A/D converter and the circuitry implied in GE drawing 711-03059. A 1-watt power increase was allowed for the A/D converter but no allowance was made for any required peripheral electronics or power supply inefficiencies. Likewise, no allowance was made for any additional circuits or power supplies required to satisfy the 711-03059 drawing. Engineering contact between GE and GAC engineers is required to arrive at a satisfactory IVS power value considering performance, reliability, and safety trade-offs.

7.7 Weight

The revision 6 specification included a weight increase equal to the weight of the CFE A/D converter which must be incorporated into the IVS. No allowance was made for mounting hardware, bracketry, or the outer housing size increase of the electronics control assembly. Also, no allowance was made for the additional connectors, wiring and circuitry and associated hardware required by the GE drawing 711-03059. Collaboration between GE and GAC engineering will result in a satisfactory IVS weight once the requirements of the aforementioned items are completely defined.

7.8 Electromagnetic Interference

There is a potential problem area involved in satisfying the specified EMI requirements. The sensor must have a window installed in order to admit the input image. This window cannot have any EMI corrective fixes applied which will reduce the illumination level or the quality of the input image. It is assumed that deviations to the specification, if required, will be granted on selected, closely controlled basis.

8.0 MAINTAINABILITY CONSIDERATIONS

Both units of the IVS are hermetically sealed making field maintenance difficult. It is understood that all IVS repair will be made at the factory.

The IVS design will take into account the requirement of effecting a repair of any malfunction without adversely affecting the reliability of any component not involved in the repair. Modular construction is to be used wherever practical so complete subassemblies may be replaced. All subassemblies and components will be made as accessible as possible once the hermetic seal is broken and the cover removed. The test points available at the subassembly interface allow for a thorough evaluation of any repair upon completion.

9.0 SAFETY CONSIDERATIONS

The design of the IVS is such that few safety hazards will be involved. The design, being all electronic, incorporates few sources of energy which could present hazards to the crew or overall system. Hydraulics, pneumatics, explosives or propellants are not required in the design. Potentially toxic or fire producing material has been minimized by material selection and packaging approach; the two subassemblies of the system are hermetically sealed inert gas filled (dry nitrogen) at 0.5 atmospheres. High voltage, 2000 VDC, is employed in the system but its use is completely internal to the sensor. Electrical shorts, should they occur in the IVS, will be isolated from the overall system by fusing provided by the vehicle electrical system.

The structure used to house and hermetically seal the two packages making up the IVS is rugged with no sharp edges and corners which could prove hazardous to the crew.

There is no known combination of materials in the design which could provide any substantial source of chemical energy that would present a hazard to the crew or to the overall system.

10.0 RELIABILITY CONSIDERATIONS

Listed below are the reliability tasks and considerations to be applied to the proposed program.

1. All parts will be burned-in for 168 hours at maximum rated power and/or voltage at maximum rated temperature. This is intended to weed out incipient failures and localize any potential reliability problems.

2. A worst case circuit design analysis utilizing the ECAP (computer aided design analysis technique) system. The data obtained from this analysis will be used to establish the application failure rate of each component part, and the subsequent MTBF for the system.

3. A preliminary reliability prediction will be made for the IVS. The data from this prediction will be used in the system and/or subassembly redundancy studies and as a guide in determining and identifying critical parts. The failure rates to be used on this program are based on MIL-HNBK-217A, FARADA, or other approved sources.

4. A complete systems reliability analysis will be conducted. This analysis will include probabilities of failure during or immediately following Qualification testing, storage, actual mission and transportation to a test site.

5. A failure modes and effects analysis will be conducted. This data will be used to evaluate parts selection, reliability problem areas and the need for redundancy.

6. A closed loop failure analysis system will be used to maintain control of vended parts and pinpoint any potential reliability problems that have not been observed in the normal screening and testing results.

7. Operating time logs will become a part of every system or subsystem test specification. This data is used to maintain control of operating hours or equipment, used in the observed system reliability analysis, and as observed data in any failure analysis.

8. A parts evaluation program will be initiated for the IVS. This program enables reliability to maintain control of quality workmanship (internal and external), process uniformity, and materials that go into the fabrication of the parts.

9. The parts that are not listed on the SPL will be specified as non-standard and selected in the order of procedure as shown below.

   (a) Qualified Established Reliability Specifications Parts

   (b) Qualified JAN Parts

   (c) Company Specification Control Drawings

11.0 THERMAL CONSIDERATIONS

The specifications for having a surface finish with an emittance greater than 0.85 does not create any design problem. Many paints will meet this requirement. A gloss paint which is easier to clean would be marginal, $0.8 < \varepsilon < 0.85$, but semi-gloss or flat paints would meet the requirements. The finish would be obtained by following an approved painting specification. The emittance would either be accepted on published test data or it would be verified by measurements. There are two ways of measuring the emittance, either by a reflectometer or an emissometer. Most measurements made in the past at GAC were done with the reflectometer where the spectral reflectance, or energy $E(\lambda)$ between 2 and 22 microns are measured and the emittance calculated for some temperature T by use of the equation

$$\varepsilon(T) = \frac{\int_{\lambda=2}^{\lambda=22} E(\lambda)\, d\lambda}{\int_{\lambda=2}^{\lambda=22} E_B(\lambda)\, d\lambda}$$

where E_B is the black body spectral energy.

This type of analysis has been automated and is programmed for data reduction on the IBM360 digital computer. Most of the future measurements will be done with an emissometer. Obtaining an LRC Emissometer, Model 25B (Lion Research Corp.) is presently in process. It is a portable unit and enables the measurements to be made on the finished items.

The cooling of the electrical box will be accomplished by limiting the heat into the contact area of the base plate, A_{B_P}, so that the base plate heat flux, $\dot{q}_{B_P}$, meets the requirements of handling the generated heat load Q within the following limits

$$\frac{0.9\ Q}{A_{B_P}} < \dot{q}_{B_P} < 1.0 \text{ watts/sq. in.}$$

The sensor head cooling will be more difficult to distribute properly. The heat generated will result in some average temperatures from

$$Q = F_{\varepsilon} F_A \sigma (T_{avg}^4 - T_E^4) + C_M (T_{avg} - T_B)$$

where

F_A = Radiation area factor

F_{ε} = Effective emittance factor

T_E = Enclosure temperature

T_B = Base temperature

C_M = Conductance of the mounting

The heat loss distribution can be obtained once all the variables are defined. The one that will be most difficult to specify will be the contact heat transfer at the base mount. The conductance C_M would have to be determined by testing.

12.0 ON-BOARD SELF TEST DESCRIPTION AND BUDGETARY ESTIMATE

12.1 General

The GE letter, Request for Proposal-RFP 159, dated 3 June 1968, requests that the technical proposal include a description and a budgetary cost estimate for an on-board self tester to be included in the IVS. Including the self tester in the IVS design results in certain penalties in design areas such as weight, power, and reliability. A self tester separate from the IVS which could be disconnected during the mission should be considered in order to minimize the penalties imposed on the IVS by the self test capability.

12.2 Concept Description

Testing of the IVS requires introducing a moving image to the photocathode of the CORRELATRON and evaluating the resulting electrical outputs of the system. It appears that all of the desired self test electrical outputs are presently available in the form of diagnostic monitoring signals. Comparator and condition indicating circuitry will have to be added or made available to the IVS to implement the self test capability.

The most practical technique for projecting a moving image on the CORRELATRON photocathode appears to be accomplished by installing a set of miniature incandescent lights, within the hermetically sealed sensor, near the erase lights. By controlling individual lights the uniformity of the illumination falling on the photocathode can be controlled and the center of power of the input image can be varied. This results in an indicated scene positional change sensed by the IVS. The turn-on and turn-off illumination increase and decay of the individual bulbs result in an apparent velocity as the scene center of power moves from one position to another. The electronics required to evaluate the IVS performance could be installed in the electronics control assembly.

The budgetary estimate of the cost for implementing the aforementioned on-board self test capability within the IVS is $250,000.

13.0 ADAPTER BUDGETARY ESTIMATE

On 26 June 1968, GAC was requested to include a ROM in the technical proposal for providing the adapter, which supports the sensor. Figure 13-1 shows the GAC understanding of the physical size of the adapter. Mechanical and thermal properties of the adapter remain to be defined by GE.

It is assumed that a precision spacer is required for each installation to compensate for the ±0.25 inch tolerance on the IVS image plane position. The spacer is considered as being of the same material as the adapter and having comparable surface finishes. Properly choosing the adapter, spacer, sensor, and the main optics mounting surface finishes should result in light- and dust-tight seals that are adequate for the IVS application. It should be noted that the sensor mounting flange is large enough to accommodate an O-ring seal, if required, while the main optics mounting flange is too small for O-ring usage. A gasket is not recommended for this application because of environmental considerations. This latter consideration necessitates the close control of the adapter and the associated mounting surface finishes.

For estimating purposes, it was assumed that no parts would protrude into the area allocated for the adapter defined on GE drawing 711-03013 and that alignment of the sensor to the main optics would be accomplished by dowels.

The budgetary estimate for providing the adapters and spacers required for the deliverable hardware during the proposed program is $10,220.

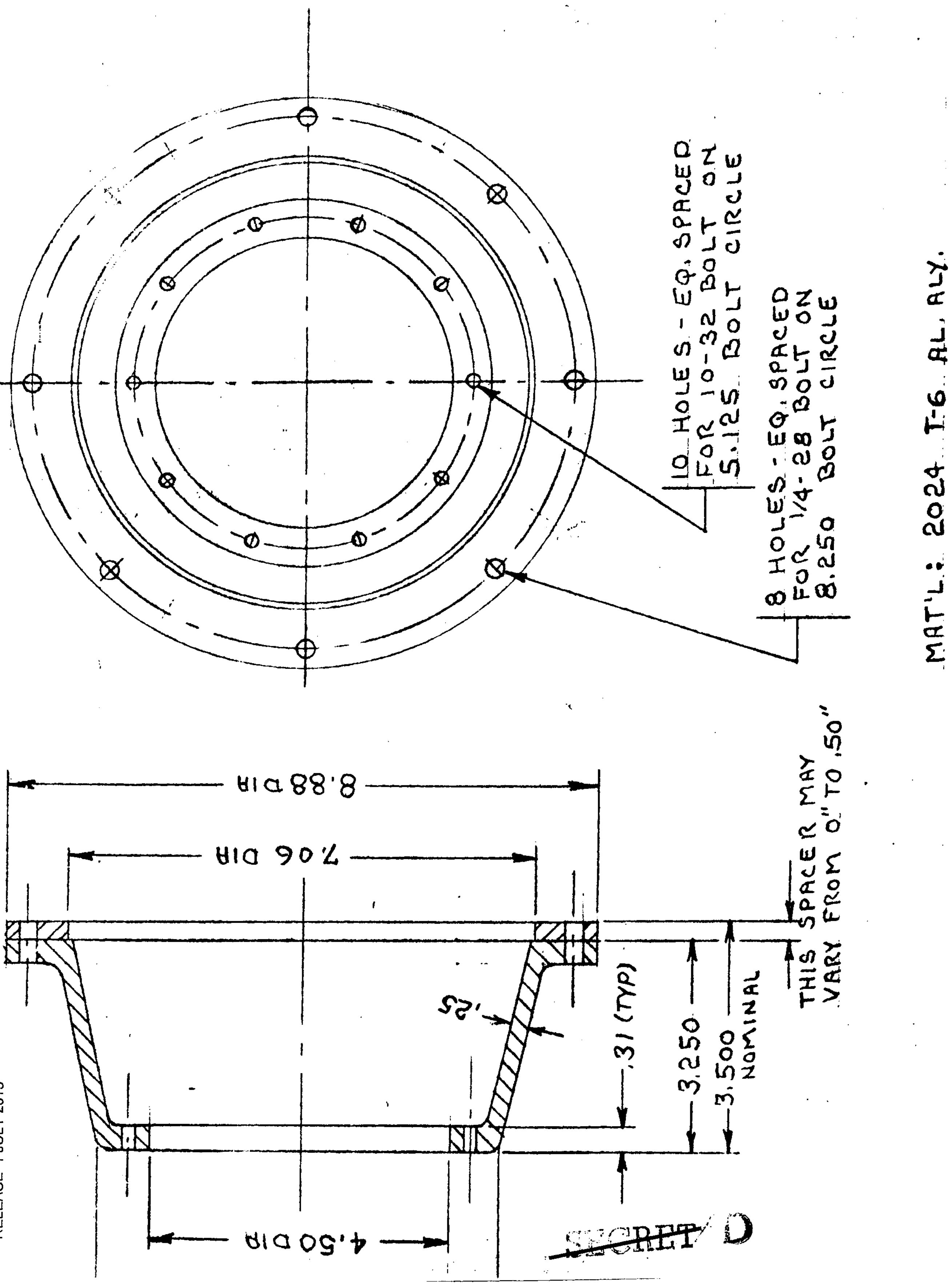

Figure 13-1 Adapter