Laats

Apollo Project Memorandum No. 1223

To: Distribution
From: D. G. Hoag
Date: 2 March 1965
Subject: CEI Detail Specification, Part I, CM Block II G&N

The following is my preliminary draft of the Secondary Characteristics section under Performance Characteristics of the Block II G&N CEI Spec, Part I. I'm sending it around in this form because it summarizes rather well the current configuration status of the Block II G&N and might be useful as well. Also I hope any errors might be discovered in time for correction in our final submittal.

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INDEX

3.1.1.2.1.1 Computer Characteristics

1. Memory
   a. Erasable: 2048 words of ferrite coincident current
   b. Rope: 36,000 words of wired transformer type tap wound cores
2. Word Length: 16 bits (15 bits data & parity)
3. Instruction Codes

a. Single precision	18
b. Double precision	3
c. In/Out servicing	7
d. Branching and interrupt control	7

4. Clock Rate:
   Oscillator: 2.048 MC
   Memory Cycle Time: 11.7 usec
5. Input, output (see Section 3.1.1.2.3)
6. Weight - Status weight per MIT Report E-1142, Feb '65
   Computer: 58.0 pounds
   2 DSKYs: 17.5 pounds each
7. Packaging: Sealed
8. Power - Status per MIT Report E-1142, Feb '65
   As drawn from +28 V dc busses
   Standby operator: 10 watts
   Operate operation: 110 watts

3.1.1 2.1.2 IMU Characteristics

1. General: The IMU is a three-degree-of-freedom gimballed system carrying inner member servo stabilized non-rotating by using error signals from three single-degree-of-freedom gyros. Three single-degree-of-freedom accelerometers are carried by the inner stabilized member.
2. Gimbal arrangement: compatible with Main Panel Flight Director's Attitude Indicators
   a. Outer axis, fixed to vehicle and parallel to vehicle X axis (roll axis). and in same direction as
   b. Middle axis, parallel to vehicle Z axis (yaw axis) when outer ~~axis~~ gimbal angle is zero. and in same direction as
   c. Inner axis, parallel to vehicle Y axis (pitch axis) when outer and middle ~~axes~~ gimbal angles are zero. and in same direction as
3. Components
   a. On Inner Gimbal (Stabilized Member) (Beryllium)
      (1) Three size 25 Single ~~Axis~~ -degree-of-freedom Inertial Reference Integrating Gyros
      (2) Three size 16 Single ~~Axis~~ -degree-of-freedom Pulsed Integrating Pendulums
      (3) Gimbal mounted electronics to service suspensions and output signals of gyros and pendulous accelerometers
      (4) Temperature control heaters and sensors
   b. On Inner Axis
      (1) Two assemblies of slip rings, 40 rings each.
      (2) Two duplex pair bearings, one fixed, one floating
      (3) One combination one-speed sixteen-speed resolver transmitter.
      (4) One single-speed gyro error signal resolver.
      (5) One d-c servo torque generator, 3 8" diameter air gap
      (6) No gimbal stops, unlimited motion
   c. On Middle Gimbal (hydroformed aluminum hemispheres)
      (1) No components
   d. On Middle Axis
      (1) Two assemblies of slip rings, 40 rings each
      (2) Two Duplex pair bearings; one fixed, one floating
      (3) One combination one-speed sixteen-speed resolver transmitter
      (4) One d-c servo torque generator, 3 8" diameter air gap
      (5) No gimbal stops, unlimited motion

3.1.1.2.1.2 IMU Characteristics (Cont.)

e. On Outer Gimbal (hydroformed aluminum hemispheres)
   (1) Blower motor and fan for heat transport from stable member to case.

f. On Outer Axis
   (1) Two assemblies of slip rings, 50 rings each.
   (2) Two Duplex pairs bearings; one fixed, one floating.
   (3) One combination one-speed sixteen-speed resolver transmitter.
   (4) One d-c servo torque generator, 3.125" diameter air gap.
   (5) No gimbal stops, unlimited motion.

g. IMU Case (hydroformed aluminum hemisphere)
   (1) Roll bonded coolant passage and quick disconnects.
   (2) Electrical sixteen-speed zero adjustment module.
   (3) Mounting pads for mounting to Navigation Base.
   (4) Two 61 pin electrical connectors.
   (5) Blower control relay
   (6) Insulation to control condensation on coolant coolant passages

4. Size: On case diameter 12.5 inches
   Along outer axis 14 inches
   Volume approx. 1100 cubic inches

5. Weight: (Status per E-1142, Feb. '65) 42.1 pounds

3.1.1.2.1.3 Optics Characteristics

The optical subsystem is the primary on-board navigation data measurement equipment. The optical subsystem in conjunction with the rest of the equipment provides

1. Means for making star direction measurements for initial alignment of the IMU
   a. visually by the astronaut
   b. automatically
2. Means for making the navigation angle measurement between navigation stars and landmark features of the earth or moon.
   a. visually by the astronaut
3. Means for making the navigation angle measurement between navigation stars and sunlit horizons of the earth or moon
   a. visually by the astronaut
   b. automatically
4. Means for making the navigation direction measurement to landmark features while in low orbit around the earth or moon
   a. visually by the astronaut
5. Means for making star occultation by the moon navigation measurements
   a. visually by the astronaut
   b. automatically
6. Means for making spacecraft backup attitude measurements with respect to selected stars for backup alignment of inertial attitude sensors.
7. A pair of articulating telescopes for general viewing by the astronaut; one high power and one low power.

3.1.1.2.1.3.1 Scanning Telescope (SCT)

The scanning telescope is a single line of sight unity power, wide field, articulating telescope used for:

1. Landmark tracking for low orbit navigation in conjunction with IMU attitude reference.
2. Acquisition instrument for the SXT.
3. Spacecraft attitude measurement for backup alignment of inertial attitude sensors.
4. Low power wide field general viewing instrument

3.1.1.2.1.3.1.1 SCT Mechanical Characteristics

1. Articulation of line of sight with respect to spacecraft.
   a. Trunnion motion $^{+50^{o}}_{-\ 5^{o}}$ of line of sight from shaft axis about trunnion axis which is perpendicular to shaft axis.
   b. Shaft motion, continuous rotation carrying trunnion axis about shaft axis located parallel to SXT shaft axis and approximately 33 degrees from the spacecraft Z axis towards spacecraft X axis in the XZ plane.
2. Trunnion axis components
   a. Servo motor-tachometer at 5952 speed with respect to trunnion prism.
   b. Resolver transmitter at one speed with respect to trunnion prism.
   c. Illuminated mechanical counter readout 000.0 degrees to 359.9 degrees of line of sight.
   d. Universal tool manual drive at 696.8 speed with respect to trunnion prism.
   e. Trunnion prism at one-half speed with respect to line of sight.
3. Shaft Axis Components
   a. Servo motor-tachometer at 2976 speed with respect to the shaft axis-line of sight plane.
   b. Resolver receiver at one speed with respect to the shaft axis-line of sight plane.
   c. Illuminated mechanical counter readout 000.0 degrees to 359.9 degrees.
   d. Universal tool manual drive at 348.9 speed with respect to the shaft axis-line of sight plane.

3.1.1.2.1.3.1.2 SCT Optical Characteristics

1. Magnification: unity
2. Field of view: 60 degrees diameter
3. Unobscured field coverage by use of articulation: approx. 50 degrees from shaft axis
4. Illuminated reticule
5. Eye relief: 2.0

3.1.1.2.1.3 Optics Characteristics (Cont.)

3.1.1.2.1.3.2 Sextant (SXT)

The sextant is a two line of sight, 28 power, telescope having one line of sight identified as the landmark line fixed parallel to the shaft axis and the other line of sight identified as the star line articulated as described below. The sextant is used for:

1. Star to landmark or horizon angle navigation measurement, manual or automatic.
2. Star direction measurement for IMU alignment, manual or automatic.
3. High power articulating telescope for general viewing.

3.1.1.2.1.3.2.1 SXT Mechanical Characteristics

1. Articulating of star line with respect to spacecraft.
   a. Trunnion motion 0 to +90 degrees of line of sight from shaft axis about trunnion axis which is perpendicular to shaft axis.
   b. Shaft motion, $\pm$270 degrees carrying trunnion axis about shaft axis located parallel to SCT shaft axis and approximately 33 degrees from the spacecraft Z axis towards spacecraft X axis in the XZ plane.
2. Trunnion axis components
   a. Servo motor-tachometer at 11,780 speed with respect to trunnion mirror.
   b. Resolver for optics hand controller cosecant attenuator at two speed with respect to the trunnion mirror.
   c. Resolver transmitter one speed with respect to trunnion mirror.
   d. Resolver transmitter 64 electrical speed one mechanical speed with respect to trunnion mirror.
   e. Trunnion mirror at one-half speed with respect to star line of sight.
3. Shaft axis components
   a. Servo motor-tachometer at 3010 speed with respect to the shaft axis - star line of sight plane.
   b. Resolver for hand controller resolution at one speed with respect to the shaft axis-star line of sight plane.
   c. Resolver transmitter one speed with respect to the shaft axis-star line of sight plane.
   d. Resolver transmitter 16 electrical speed one mechanical speed with respect to the shaft axis-star line of sight plane.
   e. Resolver transmitter one-half speed with respect to the shaft axis-star line of sight plane.

3.1.1.2.1.3.2.1 SXT Mechanical Characteristics (Cont.)

4. Star tracker
   a. Carried by head of sextant and rotates with shaft motion.
   b. Uses portion of trunnion mirror for trunnion motion.
   c. Star tracker field one-half by one-half degree.
   d. Provides following signals
      (1) trunnion error
      (2) shaft error
      (3) star present discrete
5. Horizon Photometer
   a. Carried by head of sextant and rotater with shaft.
   b. Line of sight is parallel to shaft axis.
   c. Provides auto-mark signal to computer when horizon brightness reaches measurement state.

3.1.1.2.1.3.2.2 SXT Optical Characteristics

1. Magnification: 28 power
2. Field of view: 1.8 degrees diameter
3. Unobscured field coverage of star line field by use of articulation: approximately 50 degrees from shaft axis.
4. Relative brightness ratio adjustment landmark line field to star line field:
5. Illuminated reticule
6. Eye relief: 2.0

3.1.1.2.1.4 PSA Characteristics

1. General: The PSA (Power Servo Assembly) is a collection of electronics in a common package which support the operation of the IMU and optics subsystem.
2. Construction: Modular packaging of associated electronic circuitry which plug into a single level header which makes up necessary intermodular interconnection and connections to the rest of the system through a wiring harness. The PSA is protected by a sealed container. Weight, status per E-1142, March 1965: 41.5 pounds.
3. Module identification for PSA:

Quantity	Name
1	DC Differential Amplifier & PVR
1	Binary Current Switch
1	Pulse Torque Gyro Calibration
1	Pulse Torque Power Supply
1	-28 VDC Power Supply
1	3200 cps 1% Amplifier
1	3200 cps Phase & Amplitude Control
2	800 cps 1% Amplifier
3	800 cps 5% Amplifier
2	800 cps AAC Filter
1	Signal Conditioning Power Supply
3	G&N Subsystem Supply Filter
1	Failure Indicator & Warning ("Gimb. Serv. Out of Limits & Gimb. Lockout Warning Indicator")
3	Gimbal Servo Amplifier
4	Motor Drive Amplifier
1	Optics Compensation
1	Two-Speed Switch
1	Cosecant Generator
1	Anti-Creep Electronics
1	Modulator & Loop Compensation
1	Tracker "X" Channel Electronics
1	Tracker "Y" Channel Electronics
1	Photometer Electronics
1	Light Dimmer
1	Power Transformer, Indicator Lights
1	IMU Load Compensation
4	1. Gimbal Servo Relay module 2. 3. } Optics Moding Relay modules 4.
1	Optics Automatic Operate Relay
1	SCT Moding
1	Buffer Ass'y
44 Modules Total	

3.1.1.2.1.4.1 PIPA Electronics Assembly Characteristics

1. General: The PIPA (Pulsed Integrating Pendulous Accelerometer) electronics listed here are packaged separate from the rest of the electronics in the PSA. The assembly includes serialized circuitry associated with particular serialized accelerometers in the IMU.
2. Construction: Modular plugging into a single level interconnection header in sealed covers.
   Weight, status per E-1142, March 1965: 7.9 pounds
3. Module Identification

Quantity	Name
3	DC Differential Amplifier & PVR
3	Binary Current Switch
3	AC Differential Amplifier & Interrogator
3	PIPA Calibration
12	Modules Total

3.1.1.2.1.5 CDU Characteristics

1. General: The CDUs, Coupling Data Units, are the interface units among the digital computer and variables of the rest of the G&N. Each CDU has two sections:
   a. An analog to digital section (a/d) accepting two-speed resolver data transmission and feeding angle incremental pulses to the appropriate computer counter.
   b. A digital to analog section (d/a) accepting incremental pulses of the variable of concern and generating an 800 cps suppressed carrier voltage proportional to the count of the input pulses. Each D to A output has associated a synchronous demodulator to generate also a ground isolated proportional DC voltage.
2. Construction: All solid state electronics, no moving parts. ~~Modular~~ Modular packaging plug into wire wrapped header in sealed container. Weight, status per E-1142, Feb. 1965: 33 pounds.
3. Configuration: There are five CDUs for computer interface used as follows:
   (1a) (a/d), Read IMU inner gimbal angles from 1 & 16 speed resolvers to AGC.
   (1b) (d/a), Send pitch error from AGC to FDAI pitch attitude error needle and to Saturn instrument unit for spacecraft control of Saturn. During coarse align mode of G&N, send inner gimbal error signal to IMU servo.
   (2a) (a/d), Read IMU middle gimbal angle from 1 & 16 speed resolvers to AGC.
   (2b) (d/a), Send yaw error from AGC to FDAI yaw attitude error needle and to Saturn instrument unit for spacecraft control of Saturn. During coarse align mode of G&N, send middle gimbal error signal to IMU servo.
   (3a) (a/d), Read IMU outer gimbal angle from 1 & 16 speed resolvers to AGC.
   (3b) (d/a), Send roll error from AGC to FDAI roll attitude error needle and to Saturn instrument unit for spacecraft control of Saturn. During coarse align mode of G&N, send outer gimbal error signal to IMU servo.
   (4a) (a/d), Read SXT trunnion angle from 64 speed resolver to AGC.
   (4b) (d/a), Send pitch service module engine command from AGC to engine servo. During optics drive operation, send trunnion error signal to SXT servo.
   (5a) (a/d), Read SXT shaft angle from 1 & 16 speed resolvers to AGC.
   (5b) (d/a), Send yaw service module engine command from AGC to engine servo. During optics drive operation, send shaft error signal to SXT servo.

3.1.1.2.1.5 CDU Characteristics (Cont.)

4. Module identification for five CDUs:

Quantity	Name
5	Quadrant Selector
4	Coarse System
5	D/A Converter
5	MSA & Quadrature Rejection
5	Error Angle Counter & Logic
5	Read Counter
1	Mode Module
1	Interrogate
1	Digital Mode
1	Power Supply
33 Modules Total	

3.1.1.2.3 Interface Lists

The following lists tabulate all electrical and function interfaces between the G&N and the remainder of the spacecraft, booster, or crew. In each list the following code is used:

1. First number - numerically assigned for use of these lists only.
2. Three digit number; when present, is the appropriate computer interface control code.
3. Interface type:
   - DE: d-c input to computer "in bit"
   - SD: Switch closure of dc
   - DC: DC proportional analog voltage
   - 800 cps: Analog 800 cps suppressed carrier or 800 cps power
   - 400 cps: Analog 400 cps suppressed carrier
   - CB: Computer dc output under program control
   - XC: Computer transformer output continuous signal
   - X-: Computer transformer output special signal
   - Y-: Computer transformer input special signal
   - YG: Computer transformer input into counter
   - XA: Computer transformer output under counter control
   - 28 VDC: 28 VDC power
   - DSKY: Associated with either or both of the Display and Keyboards
   - ~~ELECLUMSNT~~ E.L.: Associated with computer data display through electroluminescent panel
   - STATUS: Associated with white status lights
   - CAUTION: Associated with yellow caution lights
   - LEB Annunciator: Lights of the Lower Equipment Bay condition annunciator
   - NAV Panel Light: Status light on navigation control panel
   - ~~Window~~ ~~Window~~
   - Counter: Degrees and decimal degrees counter
   - Eyepiece: Eyepiece
4. Interface name: The name assigned to the function is underlined.
5. Number in parentheses is that used in minutes of the Integrated Guidance and Control Implementation Meetings at MSC.
6. Description of Interface

3.1.1.2.3.1 Mode Control

1.	004	DE	Ullage Thrust Present (106), Signal from Saturn indicates SIVb engine is burning to cause G&N thrust acceleration integration.
2.	007	DE	Lift Off (108), Signal from Saturn indicates first motion of booster.
3.	068	DE	Guidance Reference Release (109), Signal from Saturn indicates to G&N that the Saturn booster guidance has ceased gyro torquing to local launch vertical trajectory plane framework.
4.	—	R	SIVb Discrete Power (112), Computer 28^{V} DC through resistor to power discretes "ullage thrust", "Lift off" and "guidance release".
5.	066	DE	SIVb Separate/Abort (42), Signal from mission sequencer indicates that SIVb is staged and is interpreted as an abort if occurs early.
6.	060	DE	LEM Attached (44), Indicates LEM is attached to CSM.
7.	067	DE	SM Separate (43), Signal from mission sequences indicates the SM is staged.
8.	065	DE	Free function (59), Indicates astronaut has selected the "free" mode of G&N attitude control wh erein the G&N responds only to hand controller acceleration commands.
9.	040	DE	Hold function (58), Indicates astronaut has selected the "hold" mode of the G&N attitude control wherein the G&N holds present spacecraft attitude except when responding to hand controller velocity commands.
10.	—	—	Auto function (-), (Indicated by not free or not Hold). Indicates that the astronaut has selected the "AUTO" mode of the G&N attitude control wherein the G&N commands spacecraft position according to computer program or hand controller velocity commands.
11.	082	DE	SPS Ready (41), Indicates that the astronaut has completed the engine start checklist and the G&N can proceed with engine RCS ullage-SPS firing cycle.
12.	158	DE	SC Control of Saturn (105), Indicates that the pilot has chosen to have the Apollo G&N guide Saturn.

3.1.1.2.3.1 Mode Control (Cont.)

13. 159 DE G&N Autopilot Control (26), Indicates the pilot has chosen primary G&N control of RCS and SPS engines for attitude and thrust vector control.

14. — SD IMU Cage, Contact closure on main panel to cause IMU gimbal to be coarse aligned to zero.

15. 083 DE Block Uplink, Signals the astronaut has selected by a main panel switch to prevent ground up-telemetry from entering computer.

3.1.1.2.3.2 Analog Signals

1.	DC	Pitch SPS Gimbal (1)	drive signal from G&N
2.	DC	Yaw SPS Gimbal (2)	drive signal from G&N
3.	800 cps	Pitch Error (6)	G&N error signals to attitude error needles of FDAIs for error display - also used in early Block II flights to SCS as "Technological Backup"
4.	800 cps	Yaw Error (8)	
5.	800 cps	Roll Error (7)	
6.	800 cps	Sine Inner (3)	IMU gimbal signals to FDAIs for indication of vehicle total attitude.
7.	" "	Cosine Inner (3)	
8.	" "	Sin Middle (5)	
9.	" "	Cos Middle (5)	
10.	" "	Sin Outer (4)	
11.	" "	Cos Outer (4)	
12.	DC	Pitch Error (10)	G&N error signals from Apollo CM to Saturn instrument unit for spacecraft steering of Saturn.
13.	DC	Yaw Error (103)	
14.	DC	Roll Error (102)	

3.1.1.2.3.3 Engine & Jet Control

1.	801	CB	+X, + pitch jet (9)
2.	806	CB	-X, - pitch jet (10)
3.	805	CB	-X, + pitch jet (11)
4.	802	CB	+X, - pitch jet (12)
5.	803	CB	+X, + yaw jet (13)
6.	808	CB	-X, - yaw jet (14)
7.	807	CB	-X, + yaw jet (15)
8.	804	CB	+X, - yaw jet (16)
9.	813	CB	+Z, + roll jet (17)
10.	816	CB	-Z, - roll jet (18)
11.	815	CB	-Z, + roll jet (19)
12.	814	CB	+Z, - roll jet (20)
13.	809	CB	+Y, + roll jet (21)
14.	812	CB	-Y, - roll jet (22)
15.	811	CB	-Y, + roll jet (23)
16.	810	CB	+Y, - roll jet (24)

1 - 16 are the 16 jets of the SM reaction control system or the 12 jets of the CM reaction control system. Switched by the SCS to SM or CM jets depending upon separation status. Jets are turned on by G&N for length of time signal is present.

17. 011 CB SPS engine on/off (25), output signal when present indicates SPS firing command; when disappears indicates SPS shutdown.

18. 407 SD Injection Sequence Start (104), output signal from G&N indicating command which starts SIVb engine firing sequence.

19. 409 SD SIVb cutoff command, output signal from G&N indicating command to shutdown SIVb engine

20. -- SD SC control of Saturn. Saturn 28 VDC switched during SC control of Saturn at main panel to power discretes "Injection Sequence Start" and "SIVb cutoff command".

3.1.1.2.3.4 Maneuver Command Signals

1.	093	DE	+ pitch manual rotation (27)	Discretes from the hand rotation controller indicating controller is out of detent and is commanding a fixed angular rate and direction about the indicated axis. (During "free" motion is acceleration and not rate.)
2.	094	DE	- pitch manual rotation (28)	
3.	095	DE	+ yaw manual rotation (29)	
4.	096	DE	- yaw manual rotation (30)	
5.	097	DE	+ roll manual rotation (31)	
6.	098	DE	- roll manual rotation (32)	
7.	018	DE	+X translation command (34)	Discretes from the hand translation controller indicating controller is out of detent and is commanding an acceleration in the direction indicated.
8.	019	DE	-X translation command (35)	
9.	020	DE	+Y translation command (36)	
10.	021	DE	-Y translation command (37)	
11.	022	DE	+Z translation command (38)	
12.	023	DE	-Z translation command (39)	

3.1.1.2.3.5 Computer Telemetry and Timing

1. 001 XC Master Clock, signal to synchronize spacecraft clock to the computer oscillator.
2. 017 X- Downlink data, serial downlink data from computer to telemetry.
3. 014 Y- Downlink start, signal indicating to computer to start sending serial downlink data.
4. 015 Y- Downlink end, signal indicating to computer to stop shifting out data and reload downlink register
5. 016 Y- Downlink sync., timing for shifting out data into telemetry.
6. 024 YG Uplink zero, uplink data bit signifying zero.
7. 025 YG Uplink one, uplink data bit signifying one.

3.1.1.2.3.6 Backup Attitude Signals

1.	817	YG	+ PITCH BMAG	Angle increment data from the gyro display coupler of SCS Body Mounted Attitude Gyros used when IMU has failed as an attitude source so as to permit the computer to generate attitude error signals.
2.	818	YG	- PITCH "	
3.	819	YG	+ ROLL "	
4.	820	YG	- ROLL "	
5.	821	YG	+ YAW "	
6.	822	YG	- YAW "	

3.1.1.2.3.7 Status Light Control

1. 441 SD Computer Warning: to master caution and warning system indicating action of computer power failure or circuit alarm.
2. 429 SD Inertial System Warning: to master caution and warning system indicating detection of IMU accelerometer, gyro, or CDU error.
3. 444 SD G&N Caution: to master caution and warning system indicating detection of IMU temperature out of limits, gimbal lock caution, computer restart, or program caution.

3.1.1.2.3.8 Unused Capability

(Not connected to spacecraft systems but retained by NASA direction)

1.	338	SD	G high light	To signal lights intended on the entry monitor to indicate high or low entry.
2.	340	SD	G low light	
3.	029	XA	Entry velocity plus	Intended for entry monitor to updown counter and comparator with SCS accelerometer integration.
4.	030	XA	Entry velocity minus	
5.	078	XA	909 bit cross out	"Cross link" capability for two computers to communicate with each other.
6.	079	XA	919 bit cross out	
7.	080	YG	909 bit cross in	
8.	081	YG	919 bit cross in	

3.1.1.2.3.9 Power

1. 28 VDC AGC power buss A
2. 28 VDC AGC power buss B
3. 28 VDC IMU operate power buss A
4. 28 VDC IMU operate power buss B
5. 28 VDC IMU standby power buss A
6. 28 VDC IMU standby power buss B
7. 28 VDC Optics power buss A
8. 28 VDC Optics power buss B
9. 400 cps DSKY electroluminescent keyboard power - from master dimmer 115 V nominal
10. DC or 400 cps MP DSKY status light power, from master dimmer, 5 V nominal
11. DC or 400 cps DSKY caution light power, from master dimmer, 5 V nominal
12. resistance DSKY numeric dimmer control, from master dimmer
13. 400 cps Optics reticles, power from S/C for optics reticules
14. 800 cps 800 cps power, to SCS as 800 cps reference for FDAI and autopilot reference.
15. 084 DE Test Lights of status indicators on main panel DSKY under program control.
16. 28 VDC Power for AGC fail indication (45), to enable lighting of AGC warning light in the event AGC power breaker is out or AGC power has failed.

3.1.1.2.3.10 Astronaut Interface, Displays

1.	DSKY	~~ELEMENT~~ E.L.	~~COMP~~ CMPTR ACTY, signifies computer activity in processing data
2.	"	"	PROG, two digit (octal) 00 to 77 signifies major program mode of computer activity
3.	"	"	VERB, two digit (octal) 00 to 77 signifies verb chosen by astronaut or signaled to astronaut
4.	"	"	NOUN, two digit (octal) 00 to 77 signifies noun chosen by astronaut or signaled to astronaut
5.	"	"	X DATA, five digits (decimal) and sign ±00000 to ±99999 displaying X variable data
6.	"	"	Y DATA, five digits (decimal) and sign ±00000 to ±99999 displaying Y variable data
7.	"	"	Z DATA, five digits (decimal) and sign ±00000 to ±99999 displaying Z variable data
8.	DSKY	STATUS	~~UPLINK~~ TLM ACTY; uplink activity, indicates the computer is receiving data from up telemetry
9.	"	"	AUTO; "Auto: attitude control mode, will execute existing attitude control program
10.	"	"	HOLD; "Hold" attitude control mode, program will respond to hand controller to hold spacecraft at present attitude
11.	"	"	FREE; "Free" attitude control mode, program will turn on jets for acceleration response to hand controller only, otherwise spacecraft in free drift
12.	"	"	NO ATT; signifies that attitude data is not available from the IMU
13.	"	"	STBY; indicates that the computer is in the power saving stand by mode
14.	"	"	KEY REL; keyboard release indicates that the internal program has attempted to display information on DSKY but found display system program busy.
15.	"	CAUTION	TEMP; indicates IMU temperature in excess of ±5°F

3.1.1.2.3.10 Astronaut Interface, Displays (Cont.)

16.	DSKY CAUTION	GIMBAL LOCK; indicates an IMU middle gimbal angle in excess of $\pm 60^{o}$ and there is consequently a possibility of reaching gimbal lock.
17.	" "	PROG; indicates a program internal check has failed.
18.	" "	RESTART; internal detection in computer signifies abnormal operation.
19.	" "	TRACKER; indicates star tracker is in acquisition status but star not acquired.
20.	" "	OPP ERR; operator error, keyboard and display program has detectediimproper use of keyboa rd by astronaut.
21.	LEB ANNUNCIATOR	CGC red light; indicates computer power supply failure or circuit alarm.
22.	" "	ISS red light; indicates IMU gyro error (tumbling IMU), accelerometer error, or CDU failure has been detected (under computer program control).
23.	" "	PGNS yellow light; indicates detection from accelerometer error, IMU temperature, gimbal lock caution, program, restart, or optics CDUs. (Under computer program control.)
24.	" "	MASTER WARNING red light; lit from spacecraft master warning detection.

3.1.1.2.3.11 Astronaut Interface, Controls

1. Stick — Minimum impulse controller, navigator's right hand control for spacecraft minimum impulse control through AGC when in "free" mode.
2. Button — Mark, signals computer instant of time as appropriate.
3. Button — Reject Mark, signals computer to reject last mark.
4. Stick — Optics controller, navigator's left hand control for aim of optics.
5. 3 pos switch — Optics mode; "computer", optics under computer program control; "manual", optics under astronaut control; "optics zero" optics driven to zero shaft and trunnion.
6. 3 pos switch — Controller speed; "hi", "med", and "lo" selects gain of optics controller to line of sight motion.
7. 2 pos switch — Controller coupling; "direct", optics controller signals X and Y drive shaft and trunnion directly; "resolved", optics controller signals X and Y are resolved into X and Y motions in field of view.
8. 3 pos switch — Tracker; "on"
9. 3 pos switch — Manual Mode; "star LOS", sets SCT to follow SXT star line trunnion angle; "offset 25°" sets SCT trunnion to 25° for simultaneous star and landmark acquisition; "landmark LOS", sets SCT to zero trunnion to look along SXT landmark line.
10. potentiometer — Reticle brightness, adjusts brightness of SXT and SCT reticles.
11. 3 pos switch — Condition lamps; "on", supplies power to all LEB white condition lamps at Nav stations; "off" turns off power to white condition lamps at Nav station; "test" lights all nav station condition lamps.
~~12. Button — Check coolant; when pushed area of IMU coolant quick disconnects is illuminated.~~
12. on SXT — Eyepiece focus for full field, long eye relief SXT eyepiece.
13. on SCT — Eyepieee focus for full field, long eye relief SCT eyepiece.
14. on SXT — Landmark dimmer, polaroid dimmer for landmark line.
15. Universal tool — Optics Door, for use of opening and shuting optics door.
16. Universal tool — ~~SXT~~ SCT shaft, to ~~position SXT~~ rotate SCT shaft directly.
17. Universal tool — ~~SXT~~ SCT trunnion, to ~~position SXT~~ rotate SCT trunnion directly.
18. 2 POS Switch — UP TELEMETRY; "Block", Computer does not accept up telemetry data, "Accept", computer accepts up telemetry data. This switch is in parallel with a similar switch

3.1.1.3.2.11 Astronaut Interface, Controls (Cont.)

19.	DSKY Button	Verb,	signifies next two digits are verb code.
20.	" "	Noun,	signifies next two digits are noun code.
21.	" "	+ ,	signifies next five digits are positive.
22.	" "	- ,	signifies next five digits are negative.
23. thru 32.	" "	0 thru 9,	digits
33.	DSKY Button	CLR;	Clear data in numeric display.
34.	" "	STBY;	Puts computer in power saving standby mode.
35.	" "	KEY REL;	Releases keyboard from manual operation for display of program data or requests.
36.	" "	ENTR;	Enters keyboard data into program.
37.	" "	CAUT RSET;	Resets DSKY caution lights under program control

3.1.1.2.3.12 Signals Available for Telemetry

The following signals are suitably buffered and conditioned for transmission to telemetry. This is not a telemetry signal list but rather a list from which a signal list can be made.

1. IMU 800 cps 1% Supply
2. 3.2 KC 28 V 1% Supply
3. PIPA +120 VDC Supply
4. X PIPA +28 VDC PVR
5. Y PIPA +28 VDC PVR
6. Z PIPA +28 VDC PVR
7. 2.5 VDC Telemetry Bias
8. AGC Temperature
9. PIPA Calibration Module Temperature
10. PSA Temperature
11. PIPA Temperature
12. X PIPA SG OUT, QUAD
13. Y PIPA SG OUT, QUAD
14. Z PIPA SG OUT, QUAD
15. AGC PWR FAIL
16. IMU Operate Discrete
17. IMU Standby Discrete
18. AGC Operate Discrete
19. OPTX Operate Discrete
20. IG 1X RES Out Sine
21. IG 1X RES Out Cosine
22. MG 1X RES Out Sine
23. MG 1X RES Out Cosine
24. OG 1X RES Out Sine
25. OG 1X RES Out Cosine
26. SXT SH Tach. Output
27. SXT TR Tach. Output
28. X PIPA SG Out, In Phase
29. Y PIPA SG Out, In Phase
30. X PIPA SG Out, In Phase
31. IG IMU Servo Error, In Phase
32. MG IMU Servo Error, In Phase
33. OG IMU Servo Error, In Phase
34. OPTX 800 cps 1%
35. PITCH CDU Attitude Error
36. ROLL CDU Attitude Error
37. YAW CDU Attitude Error
38. Shaft CDU DAC Out
39. Trunnion CDU DAC Out
40. (3) Axis Nav. Base VIB: record
41. (3) Axis PIP: record
42. IMU Heater Current
43. Tracker X Fork Drive
44. Tracker Y Fork Drive
45. Tracker P/A Out
46. Photometer P/A Out
47. SCT SH Tach. Out
48. SCT TR Tach. Out
49. Pitch CDU Fine Error
50. Roll CDU Fine Error
51. Yaw CDU Fine Error
52. SXT SH Motor Control Winding
53. SXT TR Motor Control Winding
54. SXT SH MDA Input
55. SXT TR MDA Input
56. Shaft CDU Fine Error
57. TR CDU Fine Error
58. IG Torque Motor Current
59. MG Torque Motor Current
60. OG Torque Motor Current
61. AGC Down Telemetry

3.1.2.1 Reliability

Guidance and Navigation subsystem failure rates shall be demonstrated by an analytical model of each subsystem for approval by NASA. These failure rates shall be reported quarterly along with an overall mission success probability analysis using an approved mission operation timeline. The existing status of G&N subsystem failure rates (February 1965) derived from the current analytical model follow. Variations in reported rates can be expected as experience with the equipment and analytical techniques indicate.

1.	IMU:	125 failures per 10^6 hours
2.	IMU electronics (PSA):	116 failures per 10^6 hours
3.	IMU/CDU:	181 filures per 10^6 hours
4.	OPTICS:	85 failures per 10^6 hours
5.	OPTICS electronics (PSA):	80 failures per 10^6 hours
6.	OPTICS/CDU	104 failures per 10^6 hours
7.	AGC:	382 failures per 10^6 hours
8.	DSKY:	20 failures per 10^6 hours

This list does not include failures arising from wearout of switches and buttons of the controls where failure models are more accurately a function of number of operations.