R. Larson

Meeting No: 130 B
Date: 15 June 1965
Location: MIT/IL
Cambridge

MINUTES OF MEETING

BETWEEN

NORTH AMERICAN AVIATION, INC. (NAA)

AND

MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

AND

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Minutes Approved:

NAA

Minutes Approved:

MIT

NASA

Note: These minutes do not constitute contract change authorization. Changes having an effect upon the provisions of either the principal's or associate's contracts must be separately negotiated with and authorized by the NASA contracting officer or his designee.

ATTENDEES

Name	Organization	Responsibility	Telephone
Fred Martikan	Link	Technical Director, AMS	
Harold Gabriels	Link	GN System Sim. Design	
A.W. Dahlberg	Link	GN System Sim.	
J.M. Fiore	GP-ASD	GN System Sim.	
J.F. Burke	Link	GN System Sim.	
C.D. Nelson	NASA-MSC	AMS	x3422
C. Olasky	NASA-MSC	AMS	x3422
Robert Frimtzis	NAA/SID	Supervisor AMS	(213)x936-8111
Earl Jones	NAA/SID	AMS-G/N	
L. Holdridge	NAA at MIT	NAA Resident Rep/MIT	x30504
R. Larson	MIT/ACSP	D&C	x30310
J.C. Dunbar	MIT	D&C	30-347
W.W. Schmidt	MIT/ACSP	D&C	30-310
W. J. Rhine	MIT/NASA RASPO	Manager	30-343
S.J. Rosty	Link	G&G Sys. Sim.	
J.L. Nevins	MIT		30-347
John Miller	MIT	IMU S.S.	30
A. Koso	MIT	Optics S.S.	30-352

Item 1: MIT Schedule

MIT started the meeting out by presenting a schedule when approved software is available prior to a flight:

a. Preliminary G and N Operation Plan available 14 and 1/2 months before flight.

b. Sign-off on the preliminary G and N Operation Plan 13 and 1/2 months before flight.

Item 2: MIT Meeting Agenda

MIT proposed to discuss the G and N system in terms of

a. Optics

b. IMU

c. Software

Item 3: Hardware Information

The third, fourth and fifth item consisted of a discussion of the proposed NASA agenda of the AMS G and N data meeting, attachment C, entitled "G and N Data Status".

3.1. G and N hardware top level drawings are of the "Block I "50" series 1,015,000.

3.2. MIT and NAA agreed that all hardware drawings were released and the following items contained hardware transfer functions

Drawing No. 1015561
1015562
1010191
1010192
1010193
1010194
1010195

(MIT indicated that these drawings were released through CCB on 9-22-64)

NAA indicated that drawings 1010191, 1010192 and 1010195 were not available at NAA. NAA was to make copies of these drawings. MIT indicated that ATP's should be used to obtain subsystem characteristics such as resolution, responses, accuracies and etc.

Item 4: <u>Optics Subsystem</u> (Alex Koso)
(Agenda Items 2.1.1, 2.1.2, and 2.1.3)

4.1. MIT handed out copies of 5 sheets of Optics Transfer Functions (N.N.)

4.2. Link requested CDU inertia and coast rate data in order to define excursions after power off. Ref. ATP 1015100

4.3. The 3 degrees deadband in the optics hand controller was verified by MIT. This is a mechanical deadband.

4.4 Q: Does the computer control the optics? A: yes

4.5. Q: What are the rates the computer updates the command angles to the optics?

4.6. MIT noted that unknown landmark sightings are not done on AFRM 012.

4.7. Q: What is the interface with the caution warning system?

A: MIT stated that no automatic malfunction detection exists in the optics system.

4.8. Q: Is there data reflecting system errors?

A: Yes, see 1015100 ATP Apollo G&N OPT

4.9. Q: What is the trunnion granularity?

A: 10 arcsec/bit LOS, 5 arcsec/bit mechanical.

4.10. Q: Does he insert A_t or 2X A_t for manual backup?

A: The dials are the true angle of LOS.

4.11. Q: Are there any inflight autocollimations made?

A: Yes

4.12. Q: Are there sextant sightings made for 204?

A: Yes, IMU align, star-moon sightings.

4.13. Q: What is tolerance on autocollimation?

A: 1 bit or 10 arc sec.

Item 5: <u>IMU Subsystem</u> (John Miller)
(Agenda Items 2.1.1 and 2.1.2)

5.1. The optics and inertial CDU's have the same transfer functions.

5.2. IMU data is given in the two-line mechanization drawing 1015562 for AFRM012.

5.3. PIPA transfer functions are in 1015561 except that the damping should be changed from 80,000 to 120,000 dyne-cm/rad/sec on the referenced drawing.

5.4. PIPA mechanization has been presented by MIT.

5.5. IMU error analysis is in R-477.

5.6. A: In maintaining inertial reference, the open-loop stabilization rate is adequate for any expected vehicle attitude rate.

5.7. Q: Are there physical limit stops on the IMU?

A: There are no physical limit stops.

5.8. Data on gimbal lock is required. No precise data on the gimbal lock condition is available.

5.9. PIPA, CDU, IMU error signal numbers (in milliradians) are required.

5.10. The effects of cross coupling between the stable member axes due to torquing during IMU alignment are negligible.

5.11. Q: MIT test data on IMU temperature control is required.

A: Test data document E-1573, quarterly technical progress report will be given.

5.12. Q: Link would like systems status reports for weight and power requirements.

5.13. Map and data viewer panel caution warning lights are on a temporary panel; the rest of the M & DV panel space is empty.

5.14. Q: IMU/CDU difference meter scaling is required.

A: An ATP to be supplied on this subject.

5.15. DSKY hardware changes from Series 50 to Series 100 G&N are minor (i.e., moistureproofing) and not noticable.

Item 6: Software (John Dahlen, Tom Lawton)
(Agenda Items 2.1.6 through 2.1.13 and 1.2)

The software on AFRM 012 is still undefined as per MIT; preliminary draft of a document like R-477 is available August 1 on AFRM 012 and a final document on September 1.

Link stated that its needs for software data for simulation included:

1. Logic Flow diagrams
2. Equations and Scaling
3. AGC timing of programs

NAA wanted to discuss the data contained in a topical outline of CORONA 92 (G and N computer flight program of AF 011, summary of program content, dated May 7, 1965). This document becomes a part of the minutes of this meeting. It represents preliminary AFRM 011 data and the comments refer to a first guess at changes from AFRM 011 to AFRM 012 by paragraphs in that document.

Item 7: MIT Comments on NAA document (Attachment C)

Reference 1: Major Mode Document, Mission 204.

Reference 2: Minutes of 204 Meeting

Paragraphs (1a), (1b), (1c), (1d), (1e) of Corona Outline (Attachment C) have no changes, only extensions.

(1f) Mission 204 logic diagrams are available and en route from NAA to Link (Reference 1).

Paragraph 1f1: in Corona Outline will be the same as in 202 document

Paragraph 1f2: will change as directed by Reference 2 (Attachment E)
The attitude indicator shows a different display; the coordinate system is different; X-Axis is down range along the launch azimuth and the Z-Axis is along the local vertical.

Paragraph 1f3: in Corona Outline is deleted.

Paragraphs 1f4a, 1f4b, 1f4c: will be different. There will be local vertical controls with no $\overline{\text{SIV}}$ B.

Paragraph 1f5: Orbital plane change prethrusting are functionally the same, but the major mode document describes it. Aim points are different (i.e., they may be orbital parameters a, e, or radii of perigee or apogee in the Hohmann Transfer). The actual aim points will be defined September 1, maybe even in terms of numerical values. (This includes Retro, Hohmann transfer, plane change, abort from orbit).

Paragraph 1f6: There will be different thrusting: Displays on DSKY's and actual guidance equations are different, cross-product steering will be the same, procedures are in major mode document.

Paragraph 1f7: Report R-467 has equations, major mode document gives logic. MIT will provide Viewgraph slides. Alignment and star selection routines are in these Viewgraph slides.

MIT Comment on Nav. Integration

Drag is not in the equations at present. They may include it if they go for several revolutions without ground station contact. Integrations is expected to have a time stop.

Paragraph 1f8: in Corona Outline: Entry

(8a), (8b) will be similar to 202

(8c) - steering equations will be different, measurement of lift and drag seems to be a requirement.

(8d) - display to indicate termination of reentry guidance? Probably to same for 204.

Paragraph 1f9: Abort

(9a) No tumbling abort is done - abort mode selection is different than on 202. Reference: "major mode document".

(9b) is deleted

(9c) is the same as on 202

(9d) similar to 202

(9e) similar

(9f) abort to orbit - see major mode document

Paragraph 2: in Corona Summary: Erasable Memory Assignment

This varies from day to day. Nouns will not change and will be defined in generality later on. Link should be kept up to date on their nouns (MIT comment).

Assignment of data codes for data retrieval is o.k. as long as we do not have the nouns defined.

IC's (Initial Conditions) are loaded by tape in the actual spacecraft.

Keyboard display program is the biggest program in the AGC.

Paragraphs 3, 4, 5, 6 and 7: in Corona Summary will not change from 202 to 204.

Paragraph 8: is called restart control, not master control. MIT will continue to change it.

a. same

b. action item on MIT - define changes

c. same

d. MIT will check

e. same

f. changes from 202 depending on what the routines are. This is a compilation of the various starts of the routines.

Paragraph 9: This item remains the same in general, additions will be required as they are developed.

Paragraph 10:

a. Substantial changes have been proposed for the format change, NASA decision is pending.

b. Changes in telemetry lists: analog telemetry is defined, digital telemetry has not been defined for 204, but is similar to 202. R-477, Rev 1, list is applicable to 204 per MIT.

Paragraph 11: T4 Rupt Output Control Programs will remain the same for 204.

Paragraph 12: Mode switching and Mark Routines will stay the same except item (12n) Keyboard lead in and Mark/Mark Reject Routine (before it was Mark accept)

Paragraph 13: of Corona: 1 PIPA compensation routine will probably have changes in scale factor.

Paragraph 14: is the same for 204

Paragraph 15: Several functions will be added but will basely stay the same except as listed. R-477, Rev. 1.

Paragraph 16: will remain the same except that some AGC checks will be stored differently (this is documented in a [redacted] memo .

STG° 170

Paragraphs 17 and 18: will be the same.

Paragraph 19: Stays the same for all earth orbital mission (scaled up to 16,000 km). Sun and moon gravitational effects are set to zero for earth orbital programs. MIT will give Link their Newton iteration scheme equations write-up. Some constants are available. Time step .075 hours in earth orbit. The integration has a six or seven digit accuracy. It takes 3 and 1/2 sec time for 1 step of the Encke integration, 4 sec for the W-matrix, total time is 7 and 1/2 sec.

Paragraph 20: This is being written now.
No document describes it at present; it is totally different from Corona 92.

Paragraph 21: for Lab testing only, no bearing or mission

Paragraph 22: is not 012 data

Paragraph 23: will be the same, subject to scaling restriction for earth orbit (same as 19)

Paragraph 24: B-vector routine will be the same for 204.

Paragraph 25: will be the same except for orientation of axes described in Paragraph 1 of Corona Summary. This is in skeletal form.

Paragraph 26: will be complete change for 204 and available Aug. 1.

Paragraph 27: will be the same plus additions.

Paragraph 28: 29: NAA ought not be concerned with them but they remain the same. They will be post-installation checkouts, not required for flight simulation.

Paragraphs 30 and 31: will be the same

Paragraph 32: will be the same functionally, but many verbs and nouns will be added.

Paragraph 33: is not required

Paragraph 34: This will undergo substantial revision.

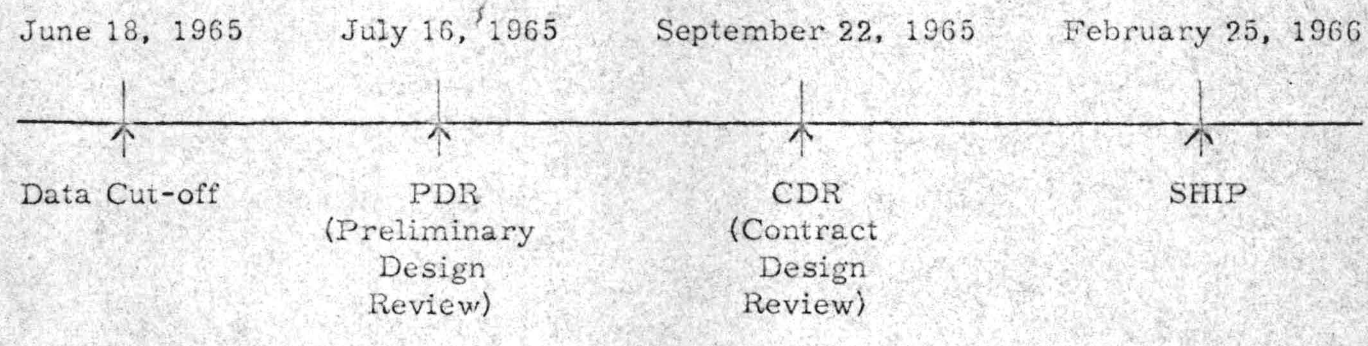
Paragraph 35: is deleted for 204.

Paragraph 36: Reentry discussion tomorrow

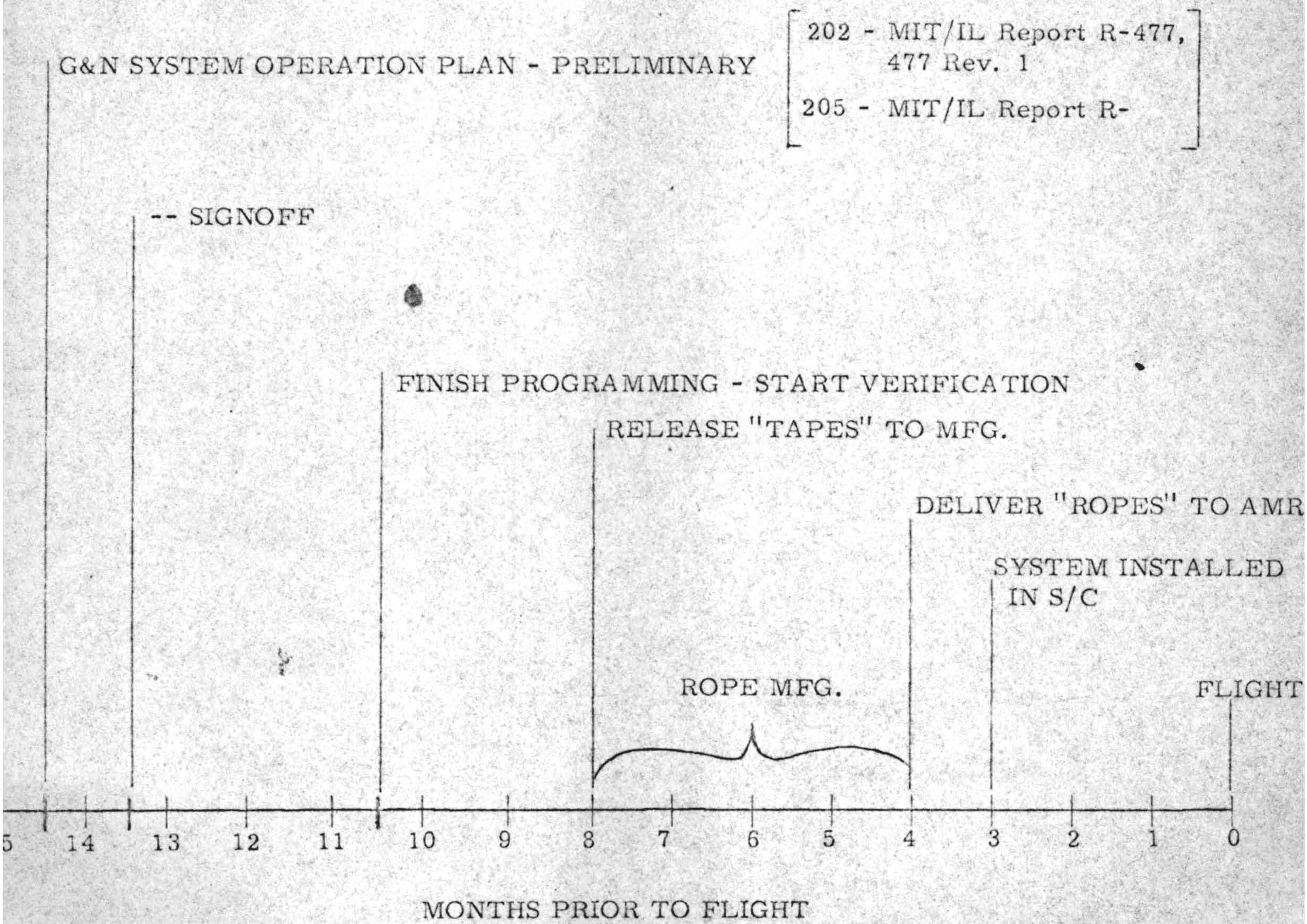
Paragraph 37: will be the same

Paragraphs 38 and 39: are deleted for 204.

Item 8: AMS SE-012 Schedule



Item 9: Guidance & Navigation Software Schedule



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G&N DISCUSSIONS AT MIT

ITEM 10 General Discussion

Discussion took place about the schedule resolution between MIT AGC flight article and the Apollo Mission Simulator.

1. Direct translation of AGC language to DDP by an interpretive program.

2. Use of actual AGC in G&N Mission simulation

3. Stretched out G&N schedule which provides a system to start with and later modifications as they come along.

4. Use assumptions to the best knowledge on the software as NAA has been doing for simulation in the past.

ITEM 11 Continuation of NAA Document on Corona 92 Discussions

Paragraph 36 of Attachment C

R-447, Revision 1 is not expected to change for 204, but MIT has been asked to look at alternatives. This is detailed enough for programming.

36a Functionally the same

36b same

36c More comprehensive to include all roll angle, more initialization points (for abort conditions)

d, e, f, g, h, i are pretty much the same

j Nav. base orientation is computed under (p) the X-Nav base axis is not defined, some discussion about the orientation of the X-Nav. base axis. There are small changes.

k will change

l is the same

m, n, o are constants only

R-447, Revision 1 includes reentry constants (page 5-15) (4-29, 4-26). Termination of steering is in. The same entry steering (paragraph 1f8c and 1f8d) programs will be used with some modifications.

Paragraph 34

Items a to k are the same for 204
l will be changed completely for 204
m to o are lunar mission programs, they do not apply to mission 204

ITEM 12 LIST OF HARDWARE DRAWINGS APPLICABLE TO AFRM 012

Printout of all drawings applicable to AFRM 012 will be supplied to NAA by MIT.

ITEM 13 APPLICABILITY OF AFRM 012 DOCUMENTS

A list of documents has been given to MIT for a verification of applicability to AFRM 012. The list of documents, with MIT comments, will form attachment B to the minutes of the meeting.

ITEM 14 LINK G&N DATA REQUIREMENTS FOR THE APOLLO MISSION SIMULATOR

The following data is useful and mandatory for a realistic simulation of the Guidance and Navigation System software.

1. Expected system malfunctions and their effects on the system.
2. Maximum, minimum values and least significant bit of each variable in the AGC.
3, Erasable and fixed memory stored data.
4. Math model equations and flow diagrams in standard engineering symbolism (i.e. not computer language).
5. Computation time for each AGC subprogram
6. Calling sequence and timeline for entire mission in addition to the calling sequence and timeline for each sub-mode.
7. Complete AGC - astronaut interface for the entire mission.
8. Interface between the AGC and the up and down telemetry.

Discussion of Item 14

Paragraph I This data is not part of mission-dependent data, not included. There is a failure analysis document available on Block I and estimate is that it is about 80% correct. Link would require a document "Failure Effects Analysis" which helps in the implementation of simulated malfunctions. This should go into the MIT data package. MIT will sit down with the lab man responsible for malfunctions an AMS and discuss these in detail.

Paragraph 2 This data is available in final form at a later date but is not a separate document at MIT. Data is available from the designer.

Paragraph 3 Some data is in R-477, not all is available at the time R-477 will be issued.

Paragraph 4 Chapter four in R-477 contains all mission-dependent equations, logic flow for sub-programs of the AGC is in Chapter III for sup-programs in the AGC. The AGC executive routine is described in R-467. All programs that fly but are non-mission dependent programs are in memos, reports. Link requested that this non-mission dependent data be referenced in R-477.

Paragraph 5 & 6 AGC timelines will be available in R-477 for future missions.

Paragraph 7 Information contained in Major Modes Document for 204 will be in R-477 with additional values of time given.

Paragraph 8 For the down-link all data and its listing are available in R-477, while for the up-link general codes and a word description exist in this document.

R-477 does not document standard programs, these are revised and available in detail in the Corona AGC language printouts.

Firmed-up documents have a short lead time of days or at most weeks. Preliminary data is available only by phone call to the individual directly involved.

Item 15 Side Meeting

Confirmation of Link design assumptions and response to questions concerning the AGC G&N Executive and Keyboard/Display simulation.

15.1 Q. Define expected use of machine address to be specified nouns, requiring knowledge of octal data addresses.

A. These are presently used for ease of program check-out. All AGC data to be loaded or displayed will eventually be addressed by appropriate verbs and/or nouns. (See R-477-1).

15.2 Automatic displays. - not presently defined but expected displays are described in "Operational Requirements for Spacecraft Guidance and Navigation," SA204 NASA, 17 May 1964.

15.3 Telemetry Downlist - R-477 described the most up to date list presently svailable.

15.4 Star data storage - Star coordinates are to be stored in fixed memory and addressed by use of the appropriate verb/noun and a two digit (decimal) ID.

15.5 Landmark data storage - A limited number 6-8 of L/M coordiantes may be stored in fixed memory. If L/M data is input (most probable solution) this will be done as two three-component octal loads, yielding three double prec. numbers - Latitude, longitude, Altitude ASL.

15.6 AGC Major Mode assignments - defined in "Minutes of 204 meeting."

15.7 Automatic mission time line - No auto time line is to be used for 204. Major programs are to be initiated by the astronaut or UDL, however related moding sequencing will proceed semi-automatically with astronaut participation. See R-477

Item 16 - Miscellaneous Questions

16.1 Q: Is IMU pressure fail indicated to astronaut?

A: No. IMU pressure sensor does not interface with caution warning system. There is no IMU pressure fail indicator in C/M.

16.2 A: MIT furnished a logic diagram for the Failure Monitor for Block I, Series 50 for SA 204.

16.3 MIT promised to furnish

1. Slides describing star selection routine for in-flight alignment program.
2. A document describing AGC self-check routines.
3. Documentation describing the new conic iteration scheme for the navigation program.

16.4 Flight Operations Manual (preliminary) has been transmitted to NASA for review. A copy is desirable for the AMS.

16.5 NAA asked whether there is a schedule at MIT for the release of a variety of technical documents such as R. E. SG etc.
MIT indicated that there is no such schedule and that these documents are generated on a random basis.

Item 17 Comments on Agenda Items

2.1.6 (Agenda Items)

a. R. 477, Rev. 1 contains information for ground update only.

b. Sighting acceptability test for both ground update and alignment. Alignment acceptability test is not presently a 204 requirement. Ground update will be available 1 August 1965.

2.1.7 3. a. (1) and (2) - Flow charts available in SA 204 minutes. Equations will be available by August 1, 1965.

(3) Not a 204 requirement.

2.1.7 d. (4) Pages 3-54 and 3-55 of R477, Rev. 1 included flow charts. Equations will be available approx. Aug 1, 1965.

2.1.8 b. (1) Part of this information will be available by Aug. 1 1965.

2.1.9 (2) Will be available by Aug 1, 1965

2.1.10 (3) Star coordinates will be provided in the equatorial inertial coordinate system in the AGC. Landmarks will be provided by 1 August 1965.

2.1.11 Will be available by Aug 1

2.1.12 Will be available by Aug 1

2.1.13 Will be available by Aug 1

S

Item 18

18.1 MIT indicated that data on CDU inertia and coast time is contained in ACSP XDE 34-(5)-529 Revision C dated 11-6-64.

18.2 MIT indicated that data on the Failure Monitor relative to IMU, CDU and PIPA thresholds (in milliradiums) is delineated on the "Failure Monitor for 204" drawing.

Item 19 NAA Comment on Schedule Incompatibilities

With regard to schedule incompatibility between AMS & MIT software, NAA indicated that the data cut-off event scheduled for June 18, 1965 represents a milestone where all design data, S/C & G&N, is cut-off. Some data will still be transmitted to Link after that date, but mainly it is data based on Link specific requests. Link will then perform a preliminary design of the AMS based on this data and present at PDR (7-19-65) an EI spec, A DDM and a Firm Cost Proposal for the SE-012. At PDR NAA and NASA will then indicate what is wanted in SE-012. In the case of the G&N, based upon the available data as of now, it is possible that an update of the G&N may be required. However, this will be determined at that time. Costs and schedules will also then be discussed based upon the amount of new data availability, data format, data firmness, and training requirements.

NAA further stated that no one at this meeting is in a position to change either the AMS or the MIT G&N schedules. It is therefore desirable to obtain the best known MIT Schedules for informal software availability for mission SA 204. NAA WILL THEN ANALYZE these availability dates and see what can be done on AMS in support of these dates.

MIT felt that this is not a desirable approach and as such they have suggested the following:

a. An actual AGC be procurred and incorporated in AMS. (These computers are now available)

b. An interpretive routine be generated by Link to obtain data from Corona

MIT further stated that due to the tight schedules imposed by NASA they cannot maintain documentation prior to the availability of the actual AGC programs. This will then make it difficult for AMS to obtain additional data prior to August 1, 1965.

MIT indicated that approximately June 30, July 1, one MIT/NASA (SA-204) meeting will be held. Approximately one week after this meeting preliminary guidance equations should be available.

NAA indicated it would be desirable to have AMS representation at such a meeting.

Item 20
MIT Comments on Schedule Incompatability

Item 8&9 define a basic incompatibility between AMS schedules and G&N software schedule. The apparant schedule difference is 6 months. The 6 months is defined by an AMS data cut-off point of 16 and 1/2 months prior to flight and the G&N Finish Program date of 10 and 1/2 months prior to flight. (Note: Since the Finish Program Data is also the start verification date, MIT anticipates program changes up to the release tape date which is 8 months prior to flight. If Link waits until this date this would be a schedule difference of 8 and 1/2 months).

The NAA/Link data cut off date is for the whole AMS. NAA/Link did not define what a G&N cut off date might be. MIT requests that NAA/Link do a study to determine what the real schedule difference is, if any does exist.

MIT pointed out that NASA's design objective is to compress their schedule and need dates. This objective obviously is incompatible for the present approach to AMS software. MIT recommends that NAA/Link perform a study towards modifying their present programming technique to allow more direct usage of MIT working programs (such as Corona printouts or computer rope memory tapes). This method would reduce or eliminate the large fixed delays necessary if the MIT data has to be reprogrammed before it can be used. MIT is currently planning this kind of support for NAA, GAEC, MSFC, and MSC in the engineering simulation areas.

Item 21 Action Items

130B-01 MIT agreed to provide the following documentation by July 30, 1965:

1. A list of all hardware drawings for System 012
2. Comments on the documents of attachment B
3. A copy of the Failure Effect Analysis
4. MIT agreed to provide NAA the data listed in Item # 7 in a data package (viewgraphs slides reprints). para 1.f.7

NAA Action Items

130B-02 NAA NAA agreed as a result of comments in Item #19 to review the apparent schedule incompatibility between the AMS 204 schedule and MIT's scheduled release of Mission 204 software and determine what can be done on AMS with the present software schedule.

130B-03 NAA NAA agreed to evaluate the adaptation of an interpretive program or some other means to enable direct use of MIT documentation format such as Corona.

130B-04 NAA NAA agreed to expedite the revised lists of programmed malfunction.

Since MIT had been requested to Review Document "Programmed Malfunctions for AMS, to: J. Nevins, MIT from: G. . Holdridge, NAA dated June 10, 1965. MIT feels that they would like to defer the review since an update revision is in process of being transmitted to them from NAA.

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ATTACHMENT A

PROPOSED AGENDA

AMS - G&N DATA MEETING

MIT, CAMBRIDGE, MASS.

1. MIT comments on Link document "AMS G&N System Design Data Review"

1.1 MIT verification of Link assumptions used in G&N design for AMS and listed in Link document "AMS G&N System Design Data Review"

1.2 Availability and/or status of MIT missing data as required by Link and listed in the following paragraphs of the "AMS G&N System Design Data Review"

2.4	3.1.4	3.2.4	3.3.3	3.4.3.1	3.5.3
3.6.3.1	3.6.3.2	3.6.3.3	3.6.3.4	3.7.3	4.1.3
4.3.4	4.4.3	4.5.4	4.6.3	4.7.3	4.8.2
4.9.2					

2. S/C 012 (Mission SA 204) G&N Data

2.1 Outstanding G&N Data for S/C 012 (SA 204) as Currently Understood by NAA

2.1.1 CDU closed loop transfer function (all 5 CDU's for both the Optics & IMU use)

2.1.2 Transfer functions of PSA and associated electronics

a. Optical hand controller electronics
b. CDU - AGC stability loop
c. IMU - CDU encoder
d. Optical CDU encoder and converter
e. PSA electronics between optical CDU and Sextant
f. PSA electronics with telescope damping loop
g. PSA electronics between optical CDU and telescope
h. PIPA electronics
i. Gyro torquing electronics

2.1.3 Sextant electromechanical transfer function (dynamics of shaft and gear train)

2.1.4 Telescope electromechanical transfer function (dynamics of shaft and gear train)

2.1.5 C/M controls and displays (mechanical and electrical) transfer functions

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Attachment A (Continued)

2.1.6 Mission Software Execution Routines

a. Position and velocity update from sightings and ground base date routine
b. Signting data acceptability test routine

2.1.7 Mission Software Task Initialization Routines

a. Plane change initialization routine
b. Hohmann transfer initialization routine
c. Incorporation of sighting data for position and velocity determination initialization routine
d. Maneuver angle based upon desired signting coordinates initialization routine

2.1.8 Mission software variables and constants

2.1.9 Mission SA 204 specified trajectory in time (position and velocity)

2.1.10 Stars and landmarks in stable member coordinates

2.1.11 SA 204 executive for chronological order of mission events

2.1.12 Nominal attitude coordinates for maneuvers

2.1.13 Nominal conic parameters and time of arrival for all thrusting modes

2.2 MIT validation of 2.1

2.3 Current data approval status

2.4 MIT data release schedule

2.5 Availability of preliminary (pre-approved) S/C 012 G&N data

2.6 Method of obtaining G&N data

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Attachment A (Continued)

Summary of G&N Link Assumptions for Agenda Item 1.1
In Support of AMS G&N Meeting

Link Paragraph in Design Data Review	
2.0	Hardware system design
2.1	IMU
2.2	IMU mode control panel
2.3	CDU
2.4.1	G&N control panel
2.5.1	AGC DSKY
2.6.1	Sextant & telescope
2.9.1	PSA
3.4.2	IMU-CDU design
3.4.2.1	AGC pulsing
3.5.2	IMU-CDU difference signal design
3.5.2.1	Meter movement
3.5.2.2	Polarity of error signal
3.1.3	IMU design assumptions
3.3.2	IMU mode control
3.3.2.1	Battery loading currents
3.3.2.2	011 and 012 compatibility
3.6.2	Optics CDU control sub-system design
3.6.2.1	Excitation for optics CDU
3.6.2.2	Mark routine
3.6.2.3	Hand control deadzone

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Attachment A (Continued)

Link Paragraph in
<u>Design Data Review</u>

3.6.2.4	CDU fail signal
3.7.2	Error detection indicator design
3.7.2.1	Detection of loss of any excitation
3.7.2.2	CDU failure activation
3.7.2.3	PIPA error signal
3.7.2.4	CDU error signal
3.7.2.5	IMU error signal
4.1.2	AGC 1/0 design
4.1.2.1	DSKY di splay operation
4.1.2.1	Verb-Noun flash rate
4.1.2.2	DSKY display response
4.1.2.3	Data monitor rate
4.1.2.4	Displayed date locations
4.1.2.5	Display persistency
4.1.2.2	AGC Verb-Noun operations
4.1.2.2.1	Verb function implementation
4.1.2.2.2	Noun data implementation
4.1.2.2.3	Double precision data entries
4.1.2.3	Data storage accessible to display and load routines
4.1.2.3.1	Erasable memory data
4.1.2.3.2	Fixed memory
4.1.2.4	Telemetry outputs
4.2.2	G&N executive control design
4.3.3	Prelaunch alignment design
4.4.2	Launch boost monitor design

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Attachment A (Continued)

Link Paragraph in Design Data Review	
4.5.3	In-Flight alinement design
4.6.2	Navigation program design
4.6.2.1	Integration of navigation subroutines
4.6.2.2	Navigation integration capability
4.6.2.3	Reference trajectory integration
4.6.2.4	W Matrix integration
4.6.2.5	Observation Geometry
4.6.2.6	Observation update
4.6.2.7	Thrust update
4.7.2	Guidance program design
4.8.2	Powdered flight design
4.9.4	Re-Entry design

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Summary of Link Data Request as Agenda Item 1. 2

Link's Design Data Review Paragraph	
2. 4	Torque optical hand controller
3. 1. 4	IMU
3. 2. 4	Temperature control
3. 3. 3	IMU mode
3. 4. 3. 1	IMU/CDU control system
3. 5. 3	IMU/CDU difference signals
3. 6. 3. 1	Telemetry signal
3. 6. 3. 2	Additional malfunctions
3. 6. 3. 3	Direct drive of sextant (delete)
3. 6. 3. 4	Auto collimation (delete)
3. 7. 3	Error warning indicator
4. 1. 3	AGC-I/O
4. 3. 4	Prelaunch
4. 4. 3	Launch boost
4. 5. 4	In-Flight alinement
4. 6. 3	Nav. Program
4. 7. 3	Guidance program
4. 8. 2	Powdered flight
4. 9. 2	Entry

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G&N Data Status in Support of Agenda
Items 2.0 & 2.1 of AMS G&N Data Meeting

AGENDA ITEM

A. G&N Hardware Configuration for 012

1. C/M Control & Display Hardware Definitions & Functional Schematics - 100% available and in 012 data packages.

2. C/M System Hardware Definitions and Functional Schematics - 100% available and in 012 data packages.

B. G&N Hardware Functional Math Models

1. IMU Gyro to Platform Gimbal Transfer Function - 100% available and in 012 data packages.

2. CDU Hardware Transfer Functions

a. CDU - Electro-Mechanical Assembly: Open loop transfer function independent of PSA - 100% available and in 012 data packages.

2.1.1 b. CDU Hardware - Closed loop transfer of CDU with PSA electronic - 0% available.

3. PSA hardware transfer functions associated with G&N subsystems

a. Electronics associated with IMU closed loop (gyro-platform) servos - 100% available and in 012 data packages

2.1.1 b. Electronics associated with the 5 CDU motor drive - 0% available

2.1.2.a c. Electronics associated with optical hand controller Characteristic deadbands and delays - 0% available

d. Electronics associated with CDU dynamic drive unputs

2.1.2.c (1) IMU-CDU encoder and converter

2.1.2.d (2) Optic-CDU encoder and converter

2.1.2.e e. Associated electronics between optical CDU and Sextant - 0% available

Attachment A (Continued)

2.1.2.g	f.	Associated electronics between optical CDU and Telescope - 0% available
2.1.2.f	g.	Electronics Associated with telescope electro-mechanical assembly - 0% available
2.1.2.h	h.	Electronics associated with PIPA - 0% available
2.1.2.i	i	Electronics associated with gyro torquing - 0% available
	j.	Electronics associated with sextant electro-mechanical Assembly - 0% available
	4.	AGC Hardware Transfer Functions
2.1.2.b	a.	Output and stability transfer functions for AGC/CDU drive to IMU platform
2.1.2.b	b.	Stabilizing transfer function for spacecraft stability during RCS & SPS thrusting modes 0% available
	c.	Operational transfer functions - 100% available in operations flight program for AF-011, Series 50 G&N configuration
	5.	Sextant Transfer Functions
2.1.3	a.	Open loop sextant electro-mechanical assy. transfer functions (Dynamics of LOS, shaft and gear trains) - 100% available
Should be agenda item	b.	Closed loop sextant transfer functions of LOS with associated PSA servo electronics (LOS, shaft, gear trains and servo electronics) - 0% available
	6.	Telescope Transfer Functions
2.1.4	a.	Open loop telescope electro-mechanical assy. transfer functions (dynamics of LOS, shaft and gear trains) - 0% available
Should be agenda item	b.	Closed loop telescope transfer functions (dynamics of LOS, shaft, gear trains and servo electronics) -0% available

7. C/M Controls & Displays Transfer Functions

2.1.5 a. Electro-mechanical transfer functions of Visual Readouts (meter, dials, and etc.) - 0% available

2.1.5 b. Mechanical transfer functions - 0% available

2.1.5 c. DSKY transfer functions - 0% available

C. Functional Inputs To G&N Systems

1. Linear acceleration math model - 100% available in the AGC Flight Program for Mission #202 and in 012 data package

2. Rotational acceleration math model - 100% available in the AGC Flight Program for Mission #202 (AF 011) and in 012 data package

3. Functional keyboard data inputs - 100% available in the AGC Flight Program for Mission #202 and in 012 data package

4. Functional uplink data inputs - 100% available in the AGC Flight Program for Mission #202 and in 012 data package

5. Functional LOS images for sextant and telescope - 0% available

D. Functional G&N Sub-System Software

1. Software to initialize sub-system configuration - 100% available in Mission #202 Flight Program and in the 012 data package

2. Software to execute G&N sub-system tasks - 100% available in Mission #202 Flight Program and in 012 data package

E. Functional Performance of G&N Hardware - based on functional acceptance tests criteria - 100% available in 012 data package

F. G&N Series 50 Crew Task Procedure - based on functional procedures but not on 012 chronological tasks - 100% available in 012 data package

G. G&N Instrumentation Requirements - 100% available in 012 data package

H. Mission Definition & Software

1. Mission software task definitions 100% available based upon program Apollo Initial Mission Directive for Mission 204 (AFRM 012) and has been transmitted to Link

2. Mission software to exectue mission task - approximately 80% available based upon AGC Flight Program for Mission #202 and in 012 data package. Software execution routine outstanding are:

2.1.6 a. Position and velocity update software from signting data and uplink data from the ground - 0% available

2.1.6 b. Software for sighting data acceptability test

3. Mission software task initialization routines - 90% available based upon AGC Flight Program for Mission #202 and in 012 data package

2.1.7 a. Initialization software outstanding:

2.1.7.a (1) Software initialization routine for plane change - 0% available

2.1.7.b (2) Software initialization routine for Hohmann transfer - 0% available

2.1.7.c (3) Software initialization routine for incorporation of sight data into the spacecraft position and velocity determination - 0% available

2.1.7.d (4) Software initialization routine for maneuver angle based upon desired signting coordinates 0% available

b. Mission data need in the mission initialization routine

2.1.8 (1) Mission software variables and constants, considered to be 0% available

2.1.9 (2) 012 specified trajectory in time, position and velocity - 0% available

2.1.10 (3) Star and landmark in stable member coordinates 0% available

2.1.11 (4) 012 executive for chronological order of mission events - 0% available

Attachment A (Continued)

(5) Nominal attitude coordinates for maneuvers 0% available

(6) Nominal conic parameters and time of arrival for all thrusting modes - 0% available

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ATTACHMENT B

APPLICABLITY OF THE FOLLOWING MIT DOCUMENTS
CONTAINING SOFTWARE FOR 204
COMPATIBLE WITH CORONA

			Source	Degree of Applicability
1.	Major Modes	(204 Flow Charts)	MIT	
2.	65-FM-65	(Operational Requirements for G&N, SA204)	MSC	
3.	SGA #5-64	W Matrix Augmentation	MIT	
4.	DG Memo 330	Navigator's Check List	MIT	
5.	R-491	Optimum Steering to Achieve Velocity	MIT	
6.	SGA #8-65	Lunar De Boost Equations	MIT	
7.	R-477	Operational Plan for Mission 202	MIT	
8.	R-467	(Sunrise 33)	MIT	
9.	SGA #34-64	Orbital Navigation Using Unknown Landmark	MIT	
10.	SGA #37-63	Powered Flight Guidance	MIT	
11.	SGA #40-63	New Statistical Formula	MIT	
12.	SGA #8-62	AGC Programming Comparison	MIT	
13.	SGA #26-62	Midcourse Attitude Maneuvers	MIT	
14.	SGA #11-64	Transition Matrix For a Circular Orbit	MIT	
15.	SGA #52-63	Midcourse Guidance	MIT	
16.	SGA #26-64	Mechanization Without B Vector	MIT	
17.	SGA #13-64	Powered Flight Steering	MIT	
18.	SGA #4-64	For Hohmann Transfer	MIT	

Attachment B (Continued)

			Source	Degree of Applicability
19.	SGA #46-64	Apollo Return to Earth Trajectory	MIT	
20.	SGA #29-64	Explicit Calculation of Perturbation Matrix C	MIT	
21.	SGA #5-65	Aborts With SPS Power During Boost Phase of Mission 202	MIT	
22.	R-479	A Unified Method of Generating Conic Section	MIT	
23.	R-382	Universal Formulae for Conic Trajectory Calculation	MIT	
24.	R-482	A Method of Orbitac Nav. Using Optical Signting To Unknown Landmarks	MIT	
25.	No Number	Midcourse Velocity Correction Determination	MIT	
26.	No Number	Coast Phase position and Velocity Determination	MIT	

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ATTACHMENT C

CORONA 96
G&N COMPUTER FLIGHT PROGRAM OF AF 011
(SUMMARY OF PROGRAM CONTENT)

1. Assembly & Operation Information

   a. Error Codes Definitions
   b. Regular Verb Definitions
   c. Extended Verbs Definitions
   d. Normal Nouns (Scaling & Decimal Point)
   e. Mixed Nouns (Scaling & Decimal Point)
   f. Major Modes Descriptions
      1) Idling
      2) Prelaunch
         a) Initialization
         b) Gyro Compassing
         c) Optical Verification
         d) Inertial Reference
      3) Booster Monitor
         a) First Stage
         b) SIVB Monitor
         c) SIVB Monitor with Tumbling
      4) Coasting Phase
         a) Maneuver to Local Vertical
         b) Local Vertical Control
         c) Coast - No Attitude Control
         d) R, V, T, updating
      5) Pre-Thrusting Phases
         a) Pre SPS 1
         b) Pre SPS 2
         c) Pre SPS 3
         d) Pre SPS 4
      6) Thrusting Phases
         a) SPS 1
         b) SPS 2
         c) SPS 3
         d) SPS 4
      7) Alignment
      8) Entry
         a) CM/SM Separation Maneuver
         b) Pre-Entry Maneuver
         c) Entry Steering
         d) Entry Steering Terminate
      9) Abort Phases
         a) Tumbling Abort
         b) Post-Tumbling Attitude Recovery
         c) Free-Fall Entry Abort
         d) Abort Thrust to Recovery Area
         e) G&N Flushed

NOTE: Equations for these programs will be provided in the next data package that are currently available.

The program descriptions for the major portion of these AGC routines are contained in MIT document #R-467 dated September 1964.

Attachment C (Continued)

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2. Erasable Memory Assignment

- a. Counter and Special Register Tags
  - 1) Interpreter Registers
  - 2) Waitlist Registers
  - 3) Temporary Storage Registers (Interrupt & Exec.)
  - 4) Long-Term Storage Registers (Interrupt only)
- b. Specific to Pinball
  - 1) Miscellaneous Reservations
  - 2) Interpreter Switch Assignment
  - 3) Storage for Phase Control
  - 4) Downrupt Program
  - 5) T4 Ruput
  - 6) Mode Switching and Match Programs
- c. Alarm Indications
  - 1) IMU Compensation Parameters
  - 2) Interlock (Keyboard Sub-routing) Registers for Gyro Routing
- d. IMU Compensation Parameter
  - 1) Pipa Bais & S. F.
  - 2) Gyro Bais Drifts
  - 3) Accel. Sensitive Drift along Input Axis
  - 4) Accel. Sensitive Drift along Spin Axis
  - 5) Delta Time for 1 Pipa
  - 6) Compensating Gyro Torques
- *e Mission Reference Variable (Position, Velocity, associated Time and IMU Stable Member Alignment)
  - 1) Reference Rectification Vectors
  - 2) Reference Deviation Vectors
  - 3) Reference Conic Position Vector
  - 4) Reference Time Since Rectification
  - 5) Time Corresponding to Position & Velocity
  - 6) Reference Conic Variable X
  - 7) Pipa Data During Accelerated Phases
  - 8) Reference to Stable Member Matrix
- *f Storage, Time Shared by Mission Programs
  - 1) Storage during Standby
  - 2) "A" Memory Location for Mid Course Navigation
  - 3) "A" Memory Location for Average G Integration
  - 4) "A" Memory System Test Usage
  - 5) "B" Memory for Powered Flight & Attitude Maneuver
  - 6) "B" Memory for Aim Point Criteria
  - 7) Re-Entry & Pre-Entry Assignments
  - 8) "B" Memory Assignment for Pre-Launch Align
  - 9) Inflight Alignment
  - 10) Attitude Control
  - 11) Mid-Course 6 x 6 Error Transition Matrix (W)
  - 12) "C" Memory Assignment for Re-Entry
  - 13) Contingencies
- *g Storage Reserved Exclusively for Self Check

3. Interrupt Transfer Routines

* 011 Variables will be changed to 012 Variables

4. Fixed-Fixed Interpreter Section

   a. Programming Symbol Definitions
   b. Process Miscellaneous or Codes
   c. Procedure for Index Addresses
   d. Double-Precision Polynominal Evaluation Routine

5. Bank 03 Interpreter Section (Program Symbol Definition)

   a. Double Precision Sine-Cosine Routines
      1) (Evaluate Hastings Polynomial)
      2) Unit Vector Routine
      3) Closed Cosine Routine
      4) Closed Sine Routine
      5) Square Root Routine
      6) Unit Divide Routine

6. Executive Programs (Program Symbol Definition)

   a. Find Job Routine
   b. Job Awoke Routine
   c. Job Priority Routine
   d. Scan Job Priority Routine
   e. Change Priority Routine

7. Waitlist (Δt should not exceed 2 minutes)

   a. 120 seconds > Routine
   b. T3 Rupt
   c. Time 3 overflow

8. Master Control

   a. Common Entry and Exit Routine for Phasing Functions (Phase Control Routine)
   b. Update the Major Mode Lights
   c. Sub Routine to Sample The Requested Major Routines Phase
   d. Particular Routines
   e. Common Sub Routines used by Phase Control
   f. Major Routines
      1) Free Fall Integration
      2) System Test
      3) Nim Game
      4) Program Stall Routines

9. Fresh Start and Re-Start (Keyboard Request to Initialize System)

   a. Initialization Sub Routine

10. Down-Telemetry Program

   a. Format Definition
   b. Down Link Data Lists (32 words)
      1) Time 1
      2) Time 2
      3) In 0
      4) In 2
      5) In 3
      6) Out 1
      7) 6 Rectification Positions
      8) 6 Delta Velocities
      9) 6 Rectification Velocities
      10) 6 Gravity
      11) 2 Additional Words

11. T4 Rupt Output Control Programs

   a. Timing
   b. Relay Word Code
   c. Routine to Zero the Optics Counter
   d. IMU CDU Drive - Serviced every 60 ms.
   e. System Failure Input Bit Monitor - Every 480 ms.
   f. Process Failure Error Signal Routine
   g. Night-Watchman Alarm Routine - every 480 ms.
   h. S4B Separate Scanner - Entered every 120 ms.
   i. Optics CDU Driving Program - every 480 ms.
   j. Bank of C Relay Routine
   k. Out 2 Sub Routine for Gyro Drive and Optic CDU Through Out 2
   l. Alternate 120 ms. Leg of T4 Rupt
   m. Optics Mode Sampling Routine
      1) Mode Check Routine
      2) Manual Zero CDU Sub Routine
   n. IMU Mode Switches Sampling - 120 ms.
   o. Manual CDU-Zero Programs for IMU and Optics DCU
   p. Waitlist Task to Complete Manual Zero (Turns off Light)
   q. Manual Optics Zero Procedure
   r. Difference Actual CDU and Desired CDU Routine
   s. Output Counter Setting for Out 2 & C-Relay Setting Constants for IMU Modes

12. Mode Switching and Mark Routines

   a. Special Time Counter Reading Routine
   b. Sub routine to Zero IMU CDU Counters
   c. Set Zero Encode Lamp
   d. IMU Zeroing Routine
   e. IMU Coarse Align Program
   f. IMU Fine Align Program
   g. CDU Lock Program
   h. IMU Re-Entry & Attitude Control Program
   i. Sub-Routine to Set K&C Relay Setting to Desired
   j. Increment Routine (CDU's)
   k. Mark Requesting Routines

Attachment C (Continued)

l. Mark System Releasing Routines
m. Keyboard Lead-In And Mark/Mark Reject Routine
n. Call Special Display Routine
o. Noun Verb for Mark Display

13. IMU Compensation Package Routine (every 2.56 sec.)

a. Gyro Torque Compensation Computation
b. Routine Accumulates Gyro Torque Compensation Commands
c. Gyro Bais Drift Compensation Routine
d. 1/Pipa for ΔV >12G - second

14. Irig Pulse Torquing Routine

a. Singe Precision with Twitch
b. Double Precision no twitch on Zero
c. Gyro Stalling Routine
d. Initialization Sub Routine

15. Extended Verbs for Moding Routines

a. Sub Routine for Checking Given Noun
b. Keyboard Request to Zero IMU Encoders
c. Keyboard Request to Coarst Align IMU
d. Coarse Align to Incremental Angles
e. Keyboard Request to Fine Align and Gyro Torque IMU
f. Etc. (Too Numerous to List)

16. AGC Self Check Routines

17. Inter-Bank Communications Routines

18. Alarm and Display Procedures & Sub Routines

19. Orbital Integration Program

a. Orbital Kepler Sub Routine
b. Interation Equations
c. Constants
d. Computing Universal Conic Function s(X) and c(X)
e. Curve Fit Program
f. R&V Sub Routines from X Function
g. Postrue Routine (Beta Vector & Initial Conditions)
h. Routine to Compute Acceleration Components
i. G Mode 12 Routine - Secondary Body Disturbing Acceleration
j. Routine for Sun Disturbing Acceleration
k. Earth Oblate Routine
l. Integration Step with Rectification Test
m. Rectify Sub Routine to Establish a New Conic
n. Difference Equation Routines
o. Orbit Routine for Extrapolating the W Matice
(pg. 286) - Nystrom Integration

20. Midcourse Navigation Game
(Routine Procedure to Accomplish Signtings)

21. Midcourse Initialization and Angle Input

*22. Orbital Integration Routines for Mission 202

23. Measurement Incorporation

   a. Incorporate Routines (Update using Navigation Measurements)

24. B Vector Routine

25. Prelaunch Alignment Program

   a. Calculate Earth Rate Routines
   b. Computation of Gyrocompass Command
   c. Vertical Erection Sub Routine
   d. Sub Routine to Compute SM Axes in REC (Coordinate - Earth (Entered))
   e. Routine - Convert Target Azimuth and Elevation to Vectors
   f. Routine to Rotate Coordinate Systems by Earth Rate Multiplied by Time
   g. Setup Star Number Display Routine
   h. Half Angle Matrix Calculation Routine
   i. Routine to Display Data (Prelaunch)

26. In-Flight Alignment

   a. Initial Condition Routine
   b. Sway Routine
   c. Memory Assignments

27. PTB Op Codes

   a. Routine to Form Double Precision Number Corresponding to CDU Angle
   b. Routine to Convert Optics Trunion Angle from Counter Reasing to DP Revolutions
   c. Log Function Sub Routines
   d. Sub Routine to Compute The Arc Tan of the Ratio of Two Functions
   e. Routine to Free DSKY

28. IMU Alignment Tests

   a. SXT-NB-IMU Find Alignment Test
      1) Calculate Misalignment Angles
      2) Calculate Transformation Matrix
   b. Calculate Horizontal Misalignment Angles

29. IMU Performance Tests

   a. Rough Check Program for IMU Gyro & Accelerometers
      1 Pipa Pulse Catch
   b. Gyro Drift Tests
   c. PIP Scale Factor Test Entry
   d. Vertical Erection Routine by Nulling PIPAS

*These routines will be changed to reflect 012 trajectory constants

Attachment C (Continued)

e. Horizontal Drift Rate Test
f. Initializes Vertical Drift Test
g. Azimuth in NB Coordinates
h. Azimuth in CER Coordinates
i. Vertical in NB Coordinates
j. Vertical in CER Coordinates
k. Computation of Accelerometer Scale Factor

30. Inflight Alignment Sub Routines

a. Calculate Gyro Torque Angles
   1) Routine for Desire SM Axis from Present SM Axes
   2) Routine for Single Axis Rotations
   3) Routine Computes Components of Star Half Unit Vectors (Star M) given Measured SXT Angles PAM and SAM

b. Axis Generation
   1) Routine for Two Star Vectors in Two Coordinate Frame - Computes Half Unit Axes
   2) Computes SXT Angle SAC & PAC Given Star Vecotr in SM Axes
   3) Computes Star Projection in XY Plane
   4. Computes Precision Angles

31. Keyrupt, Uprupt, Fresh Start

32. Pinball Game Buttons and Lights

a. Keyboard and Display Program
   1) Eraseable Memory Assignment for Keyboard
      a) Buffer Storage for Display and Lead Routines
      b) Reserved for Exectuive Action
      c) Reserved for Interrupt Action
      d) Temporary Storage Executive Action (has Scale Factor Select Routine)
      e) Temporary Storage for Interrupt Action
   2) Input Code Definitions
   3) Scale Factors
   4) Noun Table Definition
   5) SF Code Routine
   6) Scale Factor Constant Code Number
   7) Routines to Read Noun Tables and Scale Factor Tables
   8) Miscellaneous Service Routines

*33. 202 Mission Control Program

a. Symbol Definition
b. Chron. Events
c. Compute Desired Spacecraft Attitude Matrix for Desired Thrust Attitude Matrix
d. Compute Vehicle Rate Computation
e. Pitch/Yaw Plane Component of DSC
f. Abort VR Computation

*The Chronological Order Events will be changed to fit 012 Mission Directive

g. Servicer Programs Updates Nominal Position, Velocity and Gravity Every Δt, Updates and Check T_{FF}, Monitors D_V. Computes U_R, V_G and B and Steering Computation
   1) CG Rotation Matrix in PD
h. Large Attitude Maneuver Control Routine for Computation and Timing
i. Roll Rate Error Routine
   1) Computes Nav Base Coordinates
   2) Resolve NBC into Spacecraft Coordinates
   3) Resolves into Gimbal Coordinates
   4) Routine Commands Spacecraft through Maneuvers by Half Angle Vector Normal to Maneuver Plane in Gimbal Coordinates
   5) Local Vertical Routine
   6) Control Routine to Set Relay Bit and Flagwords

34. Powered Flight Sub Routine

a. Routine to Read CDU and Compute Sin & Cos Functions for Present and Desired CDU Angles
b. Routine Computes CDU (Gimbal) Angles given Nav Base Axes as 3 Half Unit Vectors in Stable Member Coordinates
c. Routine Computes the Matrix to Transform SM Coordinate to Nav Base Coordinate
d. Routine Transforms a Matrix of Half Unit Vectors along S/C Axes into a Matrix of Half Unit Vectors along Nav Base Axes
e. The reverse of (d) NB→S/C
f. Routine Computes Δ Angular Changes in CDU (Gimbal) Angles for Δ Angular Changes about SM Axes
g. Routine Computes Δ Angular Changes about Nav Base Axes from Δ CDU Angle Changes
h. Routine Resolves the Small Angle Vector Stored as SM Components into Commanded CDU Angle Changes
i. Routine Defines Sequence of Maneuver Spacecraft to Orient from the Present to the Desired Attitude without Exceeding Gimbal Lock - Maneuver is along Roll Axis or in the Pitch/Yaw Plane
j. Routine Computes in CDU Gimbal Angle and Resolves Them into Δ Change about Spacecraft Axes
k. Routine Computes the Free-Fall time from Present Position and Velocity to the Interface Altitude
l. Series of Closed Sub Routines Compute required Velocity, Velocity-to-be Gained, Modified B Vector for Different Phase of Mission.
m. Routine to Compute V_R to Achieve a Circular Earth or Moon Centered Orbit
n. Routine Computes V_R to Achieve Hyperbolic Velocity for Trans Earth Injection
o. Routine Computes V_R a Trans Lunar Ellipse defined by Target Vector and Semi Major Axis
p. Routine Computes the Desired Thrust Direction as a Half Unit Vector X SC

35. Dummy 202 Initialization

36. Re-Entry Control

   a. PIPA Update Routine and Average G Routine and Update Position and Velocity every 2 seconds
   b. Control for Phases of Entry
   c. Routine to Maintain Initial Roll
   d. Huntest Routine - Check Predicted Range with Desired
   e. Routine to Predict Ranges for Each Phase of Trajectory
   f. Routine for Up Control for Supercircular Phase
   g. Routine to Maintain Constant Drag
   h. Routine for Sub-Orbital Control
   i. Final Routine to Compute Roll Command, Check Lateral Error and Steer
   j. Routine to Predict and Set Pitch Angle for 2nd Entry Condition
   k. Routine when Terminal Altitude is Reached
   l. Sub-Orbital Reference Trajectory
   m. Conversion Constants for Free Fall Integration Program
   n. Powered Flight Vehicle Constants
   o. Temporary Values for Prelaunch Constants
   p. Closed Sub Routine to Compute Desired Nav Base Orientation Needed During Entry Phase

37. Average G Integrator

*38. Dummy Re-Entry Initialization

39. Verification Assistance Program (Page 669)
Pages 669-824 are Program Dictionary and Memory Utilization

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ATTACHMENT D

The following documents were transmitted to NAA:

1. Schematics of Optics Transfer Functions (5 sheets)

2. Drawing No. 1015100 Rev. F - Functional Diagram Optical System Block I (one copy only)

3. Drawing No. 1010191 - Functional Diagram Optical System G&N 012 & 017 (one copy only of this updated version of Item 2 was received)

4. IMU Coupling and Display Units by John Deist 8/1/63 MIT Document

5. Failure Monitor for Block I, Series 50 for SA204 (one copy only)

6. PWG No. 1010804 Meter, Electrical Indicating - Yaw, Pitch, Roll Special Specification Control Drawing (two pages per drawing, one copy only)

7. Drawing No. 1015533 Dial, 1800 Speed (one copy only)

8. Drawing No. 1012512 Counter Rotating (one copy only

9. R-477 Rev. 1 Operational Flight Plan for Mission 202

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ATTACHMENT E

MINUTES OF MEETING
ON SPACECRAFT GUIDANCE AND NAVIGATION
OPERATIONAL REQUIREMENTS FOR MISSION SA-2[illegible]

OPTIONAL FORM NO. 10 5010-107
MAY 1962 EDITION
GSA GEN. REG. NO. 27

UNITED STATES GOVERNMENT

Memorandum

TO : Distribution DATE: MAY 2 5 1965

In reply refer to: PS6/M160

FROM : PS6/Chief, System Integration Branch

SUBJECT: Minutes of Meeting on Spacecraft Guidance and Navigation Operational Requirements for Mission SA-204

The following action items and agreements resulted from the meeting on May 20-21, 1965, at MSC, Building 2, for the purpose of defining AGC programming requirements for Apollo mission SA-204. The agenda and list of attendees are attached as enclosures 1 and 2 respectively.

Reference is made to MSC Internal Note No. 65-FM-65, "Operational Requirements for Spacecraft Guidance and Navigation SA-204," dated May 17, 1965, and enclosure 3, MIT Memo "Major Modes for Manned Flights." dated May 18, 1965.

Action Items

1-1 The approved Guidance and Navigation operations plan for SA-204 is due September 1, 1965. A first draft of the plan is due August 1, 1965, and a draft of the Guidance Equations and Preliminary error analysis is due June 15, 1965.

1-2 Paragraph 2.1.1.3 (Maneuver Vector) of MSC Internal Note 65-FM-65 required ΔV up-date instead of (a) and (e) up-date. J. Funk is to assess AGC impact on this requirement. M. Jenkins and J. Funk are to resolve the requirement for this type of up-date by June 20, 1965.

1-3 MIT should investigate the techniques of evaluating the change in aerodynamic characteristics of the CM due to center of gravity shifts and shape changes during reentry for the purpose of providing more accurate reentry guidance. Results are due by June 25, 1965.

1-4 Mr. P. C. Shaffer of MSC/FCD will define the parameters to be displayed on the DSKY by the AGC for each phase of the mission and the sequence of displaying the parameters. This should be available by July 1, 1965.

1-5 MIT (J. Dahlen) will provide attitudes required for navigational sightings during earth orbit by June 15, 1965, including a sequence of roll attitude maneuver requirements for the S-IVB during the 2 orbits that the spacecraft is attached.

1-6 MSC (R. Ward) will provide MSFC with the maneuvers to be performed by the S-IVB in order to have this implemented by the MSFC computer and control system. Due by July 1, 1965.

1-7 MIT should review MSC Internal Note 65-FM-65 and define the difficulties in fulfilling the requirements specified by June 25, 1965.

1-8 MSC (J. Funk) will define the free fall entry altitude to be either 400,000 feet or 300,000 feet. Due by June 25, 1965. See agreement 1-6.

1-9 Mr. C. Huss should define the following for 204 by June 25, 1965:

a. recovery area
b. acceptable orbits
c. minimum free fall time (T_{ff})
d. ground verification time for contingency insertion.

1-10 MSC (A. Cohen) will define if there is a requirement to check the MSFC and MSC platforms alignment through ACE. Due by June 25, 1965.

1-11 Mr. M. Jenkins will provide the tracking network uncertainties to be used in the preliminary error analysis by May 30, 1965.

1-12 MIT shall provide a time sequence to the logic sequence of enclosure 3 by June 30, 1965.

Agreements

1-1 The reference for the right handed, earth centered, orthogonal Cartesian set of axes stated in paragraphs 2.1.1.1 of MSC Internal Note 65-FM-65 shall be the first point of aries on October 15, 1966.

1-2 The guidance system can provide de-orbit steering using the RCS; however, automatic engine on-off is not available. This function must be provided manually although it can be based on start and stop times provided by the G&N. It is very difficult to see how the function can be provided for SA-204 without a schedule slip. It is recommended by ASPO that this not be implemented for the Block I flights. Block II configurations have this capability (SA-207).

1-3 The AGC shall have the capability of storing targeting data for at least two consecutive maneuvers.

1-4 MIT should provide the software capability for rough combustion re-start.

1-5 The crew and the AGC must have the capability of controlling any burns.

1-6 MIT should use 400,000 foot as the free fall entry altitude until further direction is given. See action item 1-8.

1-7 The IMU shall be aligned for SA-204 such that the FDAI has 90° in pitch (+ X down range) and 180° in roll, (+ Z down) and 0° in yaw at guidance reference release. This will align the horizon on the FDAI with the horizon as seen by the astronaut out the window.

1-8 The time display on the DSKY for free fall should be Minutes (2 registers)- Blank (1 register) - Seconds (2 registers). The capability for any call from the AGC through the DSKY should provide for Hours - Minutes - Seconds.

1-9 One to two minutes should be used as the time required for MSFN insertion confirmation.

1-10 Below approximately 64% thrust level is used as S-IVB shut down for the engine on/off lights. The Apollo Guidance System shall monitor acceleration for S-IVB shut down.

1-11 The next meeting will be held the last week of June.

Aaron Cohen

Aaron Cohen

Enclosures

AGENDA

1. Proposed MSC Guidance requirements.
2. Systems Constraint -MSC
3. Guidance Status based on Preliminary Mission Profile -MIT

ATTENDEES

Name	Organization
A. Cohen	MSC/ASPO
L. DeLuca	MSC/AFSB
O. Lindsey	MSC/AFSB
R. Ward	MSC/ASPO
G. L. Hunt	MSC/MPAD
K. L. Jordan	MSC/FCSD
C. Thomas	MSC/FCSD
B. G. Niedfeldt	Bellcomm
M. Fox	STL
E. Blackburn	STL
E. Crum	MSC/MPAD
W. Nixon	MSC/MPAD
C. Huss	MSC/MPAD
M. Jenkins	MSC/MPAD
T. Skopinski	MSC/MPAD
T. Gibson	GCD
J. Nevins	MIT
J. Dunbar	MIT
R. Larson	MIT/ACSP
H. Walbrecher	GE
J. Dahlen	MIT
W. Marscher	MIT
J. Shillingford	MIT
J. Suomala	MIT
R. Rose	MSC/FOD
P. Shaffer	MSC/FCD
R. Zedekar	MSC/FCSD
C. Nelson	MSC/FCSD
R. Braslau	STL
R. L. Berry	MSC/MPAD
T. Lawton	MIT
J. Funk	MSC-G&CD
H. Harman	MSC/FCD
R. Aruffo	FCD/MIT

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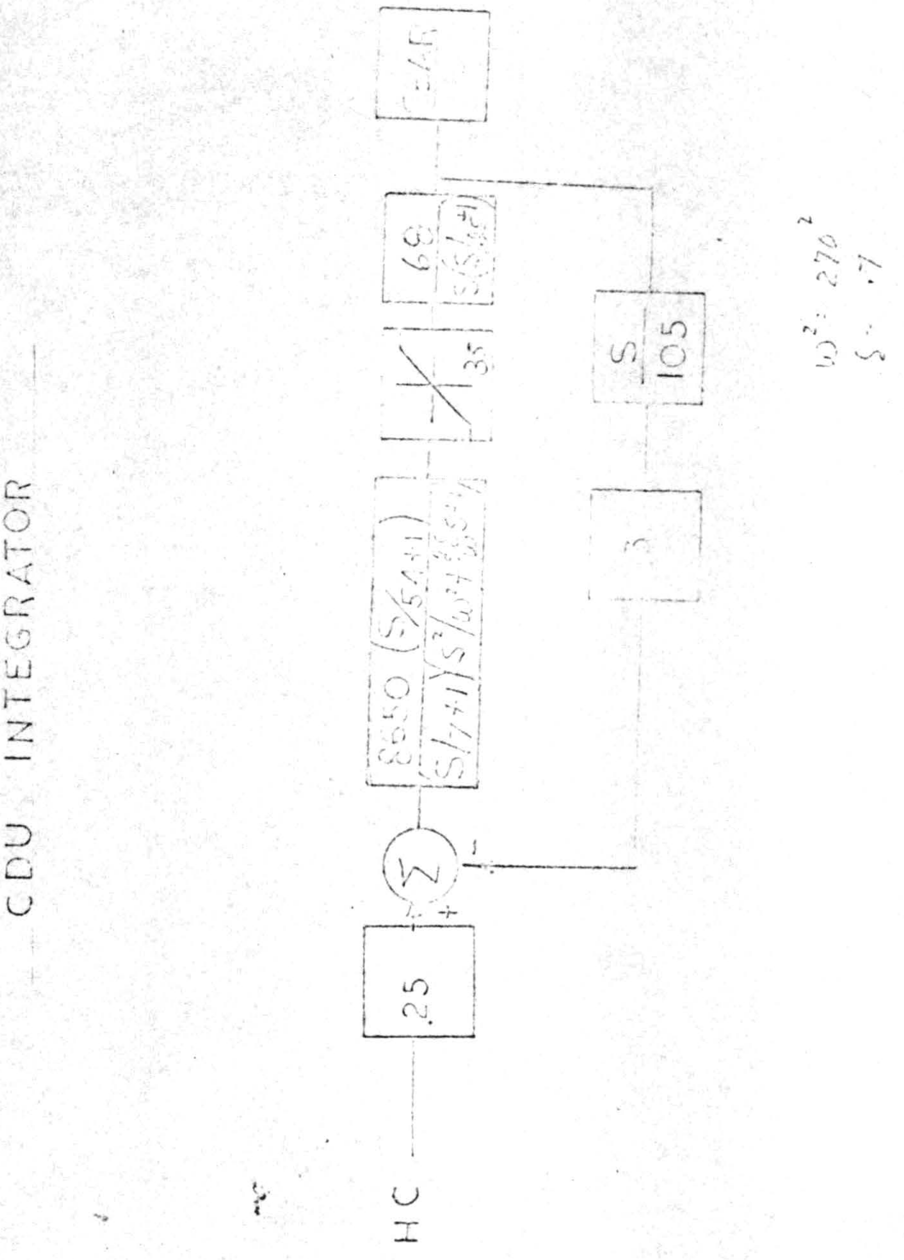
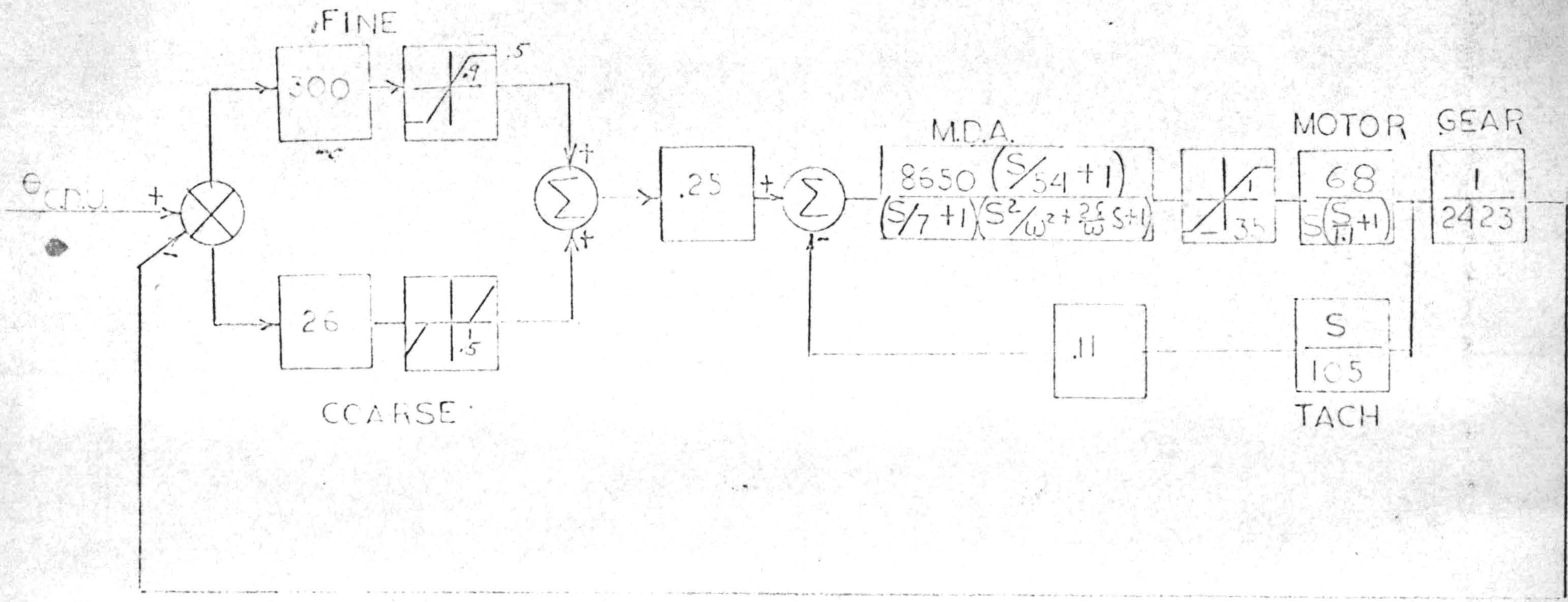
ATTACHMENT F

OPTICAL TRANSFER FUNCTIONS & PIPA ELECTRONICS



SEXTANT A_T FOLLOWS A_T C.D.U.



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$\zeta = .7$

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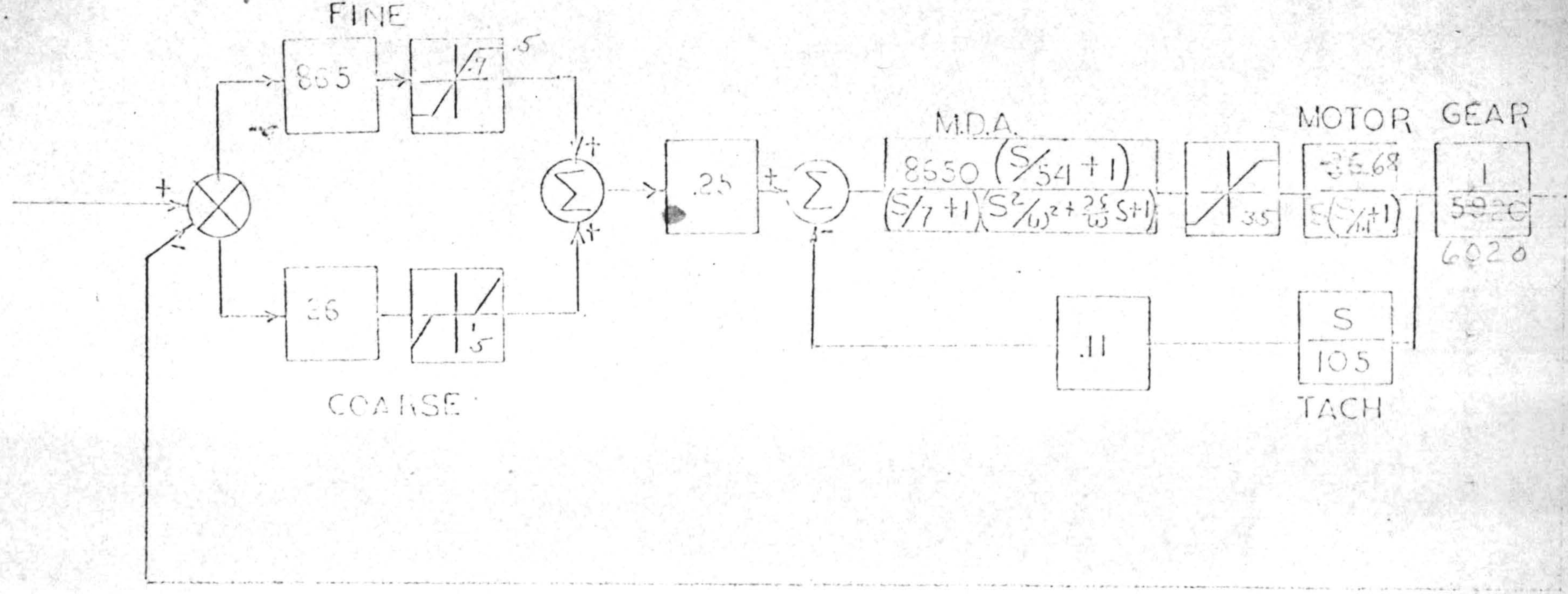
SEXTANT A_S FOLLOWS C.D.U.



$\omega^2 = 270^2$

$\zeta = .7$

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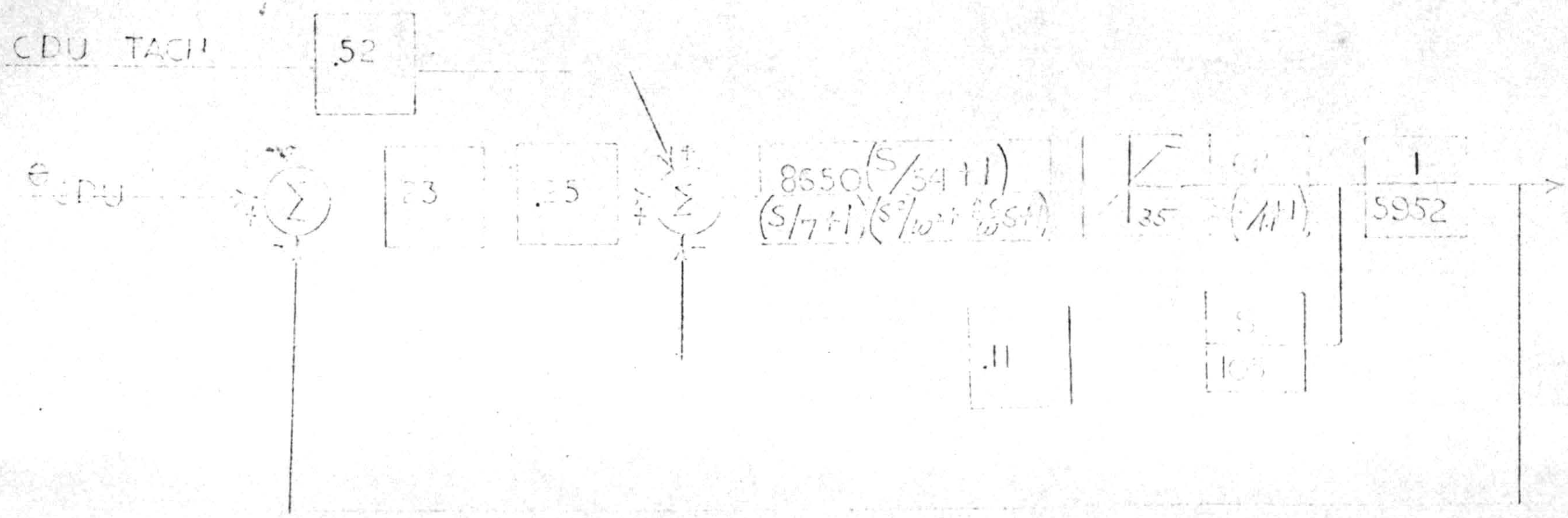
SCT A_T FOLLOWS C.D.U.



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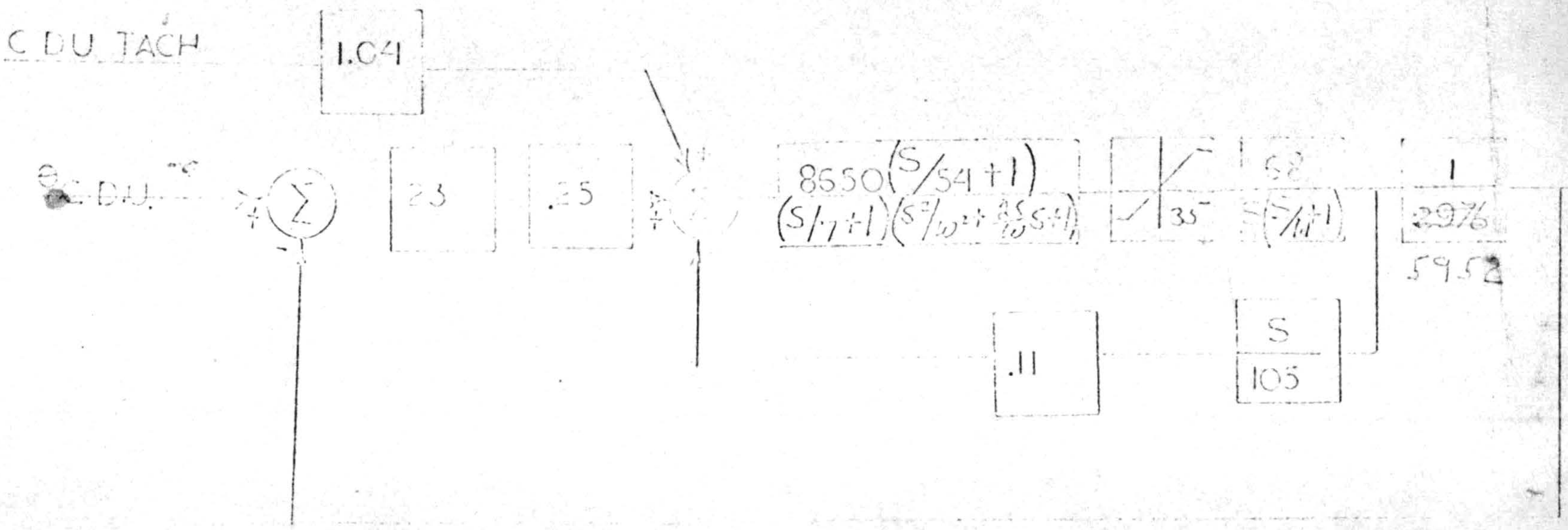

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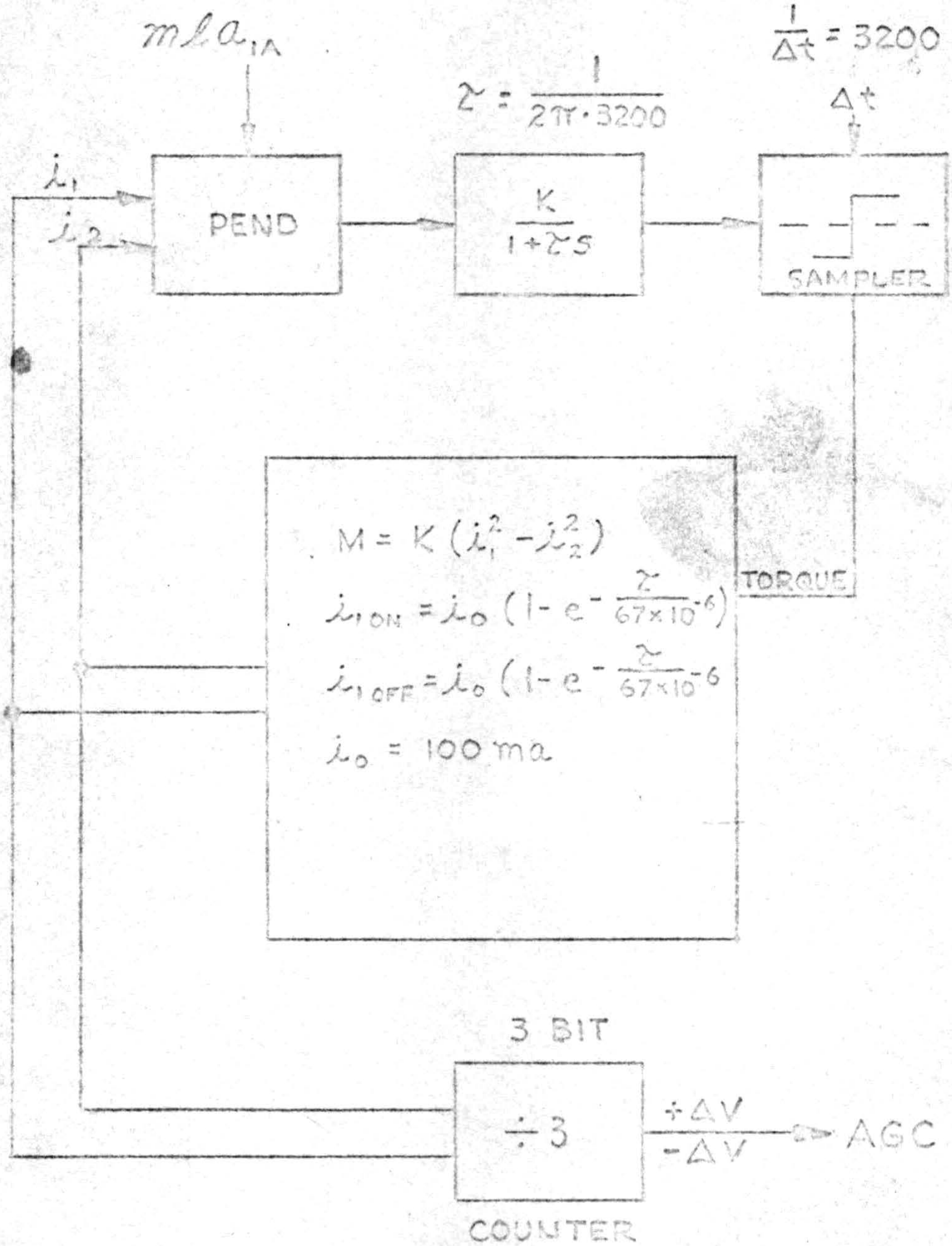

PIPA LOOP