

39 pages



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

✓ SEP 23 1968

REPLY REFER TO:

Mr. Harold T. Luskin
Apollo Applications Program Director
NASA Headquarters
600 Independence Avenue, S.W.
Washington, D. C. 20024

Dear Hal:

The Apollo Guidance Software Task Force, which I convened last December, conducted a long and thorough review of how flight software is developed and verified. It is a long and difficult process, easy to underestimate.

I am enclosing a draft of the Final Report of the Task Force, in which we made several recommendations applicable to AAP. In particular, we recommended a thorough early effort (including detailed crew timelines and mission rehearsals in a suitable simulator) to define software and crew/computer requirements.

It seems to me we are getting close to the time to begin such an effort for AAP. I would appreciate it greatly if you would review, with me and with the other members of the Task Force, how you intend to organize and carry out the development of all AAP flight software. October 2, 1968 seems a suitable date. Mr. W. G. Heffron (Area Code: (202) 484-7970) will coordinate the meeting for me. I suggest we have it here at Headquarters.

Sincerely yours,

George E. Mueller
George E. Mueller
Associate Administrator
For Manned Space Flight

Enclosure

*AAP = SkyLab



Keep Freedom in Your Future With U.S. Savings Bonds

* AAP = Apollo Application Program

Clater renamed Skylab -

IBM did the computer
programming / hardware
for SL

did same for
Apollo spacecraft)

7/10/SEP 1998

PROPOSED AGENDA

* AAP FLIGHT SOFTWARE

1. Short Review of AAP Missions
2. Assignments of Responsibility to MSC and MSFC for Flight Software
3. Management Structures
4. Process by Which Software Requirements are to be Developed
5. Software Development and Verification Process
6. Personnel Loading Required and Available
7. Facilities Required and Available
8. Schedules, Extending from Development of Requirements to Readiness for Flight

FINAL REPORT

APOLLO GUIDANCE SOFTWARE TASK FORCE

September 23, 1968

APPROVED _____

G. F. MUELLER
Chairman

FINAL REPORT

APOLLO GUIDANCE SOFTWARE TASK FORCE

1. Introduction

This is the final report of the Apollo Guidance Software Task Force, which was established by Dr. G. E. Mueller, Associate Administrator for Manned Space Flight, NASA, at the request of Lt. General S. C. Phillips, USAP, Apollo Program Director.

The purpose of the Task Force was stated in a letter dated December 18, 1967 from Dr. Mueller to Dr. R. R. Gilruth, Director, Manned Spacecraft Center, as "to determine whether there are any additional actions which could be taken to improve the software development and verification **process** and our visibility and control of it."

The Task Force was chaired by Dr. Mueller; membership is given in Enclosure 1. Fourteen meetings were held at locations and dates given in Enclosure 2. Minutes of the meetings were published and action items were assigned and accomplished. All are available from the secretaries of the Task Force (given in Enclosure 1).

This final report presents, briefly, the major topics of discussion, the Task Force's recommendations for further Apollo Program action and for treatment of software in advanced programs, and the conclusions drawn by the Task

Force as a result of the presentations made to it; by the organizations involved. The minutes and action items serve as a full report on the Task Force's activities.

2. Major Topics of Discussion

Although the Task Force reviewed all aspects of software development from initial establishment of requirements to post flight analysis, the major topics of discussion were as follows:

1. The assignments of responsibility and participation by the numerous organizations involved in or affecting software.

2. Coordination and control, informally and through documents and specifications, as they affect interfaces between software and hardware, software and crew procedures, requirements for software, design data required for software development and verification, and compatibility between the Primary Guidance Computer and the Abort Guidance System in the Lunar Module.

3. Software coding techniques, procedures and management.

4. Software schedule performance and visibility.

5. Software testing requirements and philosophy.

6. Application of trainers and hybrid simulators to software verification.

3. Recommendations for the Apollo Program

Several reconmendations of the Task Force hnvce already been acted upon. The following additional recom- mendations are made.

I. The difficulties in software development reflect the complexities of the Apollo mission; and will continue to require top level management attention at MSC and MSFC. Management procedures and working arrangements as presented appear satisfactory. Since so many organiza- tions are involved, it is recommended that MSC and MSFC provide formal definition of the organization interfaces and responsibilities between MSC and MSFC, and internally to those centers.

II. Control of constants, coordinate systems, opera- tional data, definition of software variables, was identified as a continuing problem in software development. The com- plexity of the Apollo Software intensifies the Task Force's concern. The Task Force makes the following recommendations:

1. MSC, MSFC and KSC management should support; use of Apollo Programs Standards for Physical Constants, Environmental Data and Coordinate Axes, amencing and extending them as becomes necessary.
2. The MSC Apollo Spacecraft Program Office Operational Data Control activity should receive continuing management attention and support. MSFC and KSC should review this effort in an active effort to improve their current data control methods.

3. Working within the present situation, MSC and MSFC should encourage standardization of the symbols and names of software variables, and promote understanding of these quantities by requiring appropriate tables of nomenclature, dictionary-like listings, etc.

III. In developing software, MSC and MSFC should require clear identification of all conditions which cause software program interlocks, error interrupts, redline restrictions, etc., preferably by the software programmer. These should be reviewed for applicability by operational system groups.

IV. The Task Force endorses the plans for increased use of hybrid simulators and trainers in hardware/software/crew interface Verification and recommends Apollo Program Office continued support of this activity.

V. The Task Force feels that software testing at KSC should emphasize verification of interfaces, and of the integrity of the program. KSC schedules should permit delivery of flight programs for both the launch vehicle and the spacecraft as late as the Countdown Demonstration Test or the Flight Readiness Test, whichever is earlier.

4. Recommendations for Advanced Programs

For Space programs such as Apollo Applications, Planetary Missions, etc., the Task Force draws the following recommendations from Apollo Program experience.

1. Experienced personnel should be assigned to the advanced program **as** quickly as possible, rather than use the early stages of an advanced program to train inexperienced people.

2. Technical organizations should spend **some** 10% of **their** time on advanced programs, so as to promote the carry over of experience.

3. A thorough, early, effort; at systems engineering is as important for the crew/computer/spacecraft system as it is for hardware. The effort should produce:

- a. A detailed System Specification, suitable as a basis for software and hardware development. Design requirements should be detailed and specific, accuracy and performance requirements should be given, and interface specifications should be thorough and complete.
- b. An Operations Handbook for the crew.
- c. A detailed mission timeline.

To insure these are realistic, they should be based on mission development and rehearsal. **work** in a suitable full-scale trainer, as well as on analysis.

4. There should be a deliberate policy of maximum carry over of guidance techniques from earlier programs.

5. There should be a similarly deliberate effort to promote simplicity.

6. In choosing a computer, particularly in determining the quantity of and the ratio between erasable and non-erasable memory, the difficulties in software development should weigh

as heavily as the more traditional hardware aspects. While a computer and its software do lend an element of flexibility, experience teaches that software is more difficult to develop than hardware, that verification of software, in particular, is a time consuming task.

7. In designing software, particular effort should be placed on avoiding or mitigating redline restrictions, error interrupts, program interlocks, etc. Those that remain should be clearly identified.

8. Present standardization of physical constants, environmental data and coordinate axes should be extended to include symbolic names and mathematical symbols for software variables.

9. Organizational structure and assignments should stress accountability for performance as well as scope of authority and responsibility. *Panels*, committees, etc., should be used to promote coordination and to formalize agreements, but not as replacements for line organizations.

6. Conclusions

The Task Force draws the following conclusions:

1. It is in basic agreement with the present software situation.
2. No major improvements remain to be made.
3. Software complexity requires a high level of communication and participation by the many organizations involved.

4. There 'is adequate software schedule control and visibility at present, although schedules and flight dates will make software a subject of' continual concern.

5. In developing confidence in software, full advantage should be taken of the several hybrid simulators and trainers. Coordination of activity and formal failure and discrepancy reporting systems must be continued.

And, as a general conclusion, the Task Force feels it is important to recognize that, software requirements will always be dynamic. As such, specifications and requirements will never be available in a comfortably early time frame. This **will** always cause accelerated development schedules. Apollo Program management must recognize, therefore, that software **will** require continual attention and effort to insure timeliness and stability. And Advanced Programs should attempt, as early as possible, to define these requirements and specifications so 'as to mitigate these problems.

7. Acknowledgment

The Task Force feels that it has been furnished full cooperation and candid testimony. The sincerity and dedication of all members of the NASA team **was** apparent. Their determination to meet the challenge of the Apollo Program is recognized, appreciated, and commended.

ENCLOSURE 1

APOLLO GUIDANCE SOFTWARE TASK FORCE MEMBERSHIP

APOLLO GUIDANCE SOFTWARE TASK FORCE

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ENCLOSURE 2

PLACES AND DATES OF TASK FORCE MEETINGS

APOLLO GUIDANCE SOFTWARE TASK FORCE MEETINGS

<u>Meeting</u>	<u>Place</u>	<u>Date</u>
1	Manned Spacecraft Center, Houston, Texas	Dec. 20, 1967
2.	Charterhouse Hotel, Cambridge, Mass.	Jan. 4, 1968
3.	Massachusetts Institute of Technology, Cambridge, Mass.	Jan. 5, 1968
✓ 4.	NASA Headquarters, Washington, D. C.	Jan. 16, 1968
✓ 5.	TRW Systems; Redondo Beach, Calif.	Jan. 24, 1968
✓ 6.	North American Rockwell Corporation, Downey, California	Jan. 25, 1968
✓ 7.	Grumman Aircraft Engineering Corporation, Bethpage, N. Y.	Feb. 3, 1968
✓ 8.	NASA Headquarters, Washington, D. C.	Feb. 9, 1968
9.	J. F. Kennedy Space Center, Cape Kennedy, Florida	Feb. 18, 1968
10.	G C. Marshall Space Flight Center, Huntsville, Alabama	Feb. 23, 1968
11.	Holiday Inn, Nassau Bay,, Texas	March 1, 1968
12.	Manned Spacecraft Center, Houston, Texas	March 2&3, 1968'
13.	Manned Spacecraft Center, Houston, Texas	May 20, 1968
14.	Manned Spacecraft Center, Houston, Texas	July 12, 1968

✓ ≡ Meeting notes available at JCS History Office

(End of List)

DRAFT

SUBJECT: Minutes of Software Task Force
Meeting #4, January 16, 1968
Case 310

DATE: February 2, 1968

FROM: W. G. Heffron
R. V. Sperry

MEMORANDUM FOR FILE

MEETING #4

The Apollo Guidance Software Task Force held its fourth meeting at NASA Headquarters, Washington, D. C. from 9 a.m. to 6 p.m. on January 16, 1968. Attendance is given in Enclosure I.

The next meetings are scheduled for January 24, 1968 at TRW Systems, Inc., Redondo Beach, California for review of Abort Guidance System Software, and for January 25, 1968 at North American Rockwell Corporation, Downey, California for review of the NARC Mission Evaluator Hybrid Simulator activities. A review of crew G & N Procedures will be conducted by Bellcomm, Inc. at the Portofino Inn in Redondo Beach, beginning at 8 p.m. on January 25, 1968.

possible
~~apparent~~ The purpose of the meeting was to define and discuss problem areas. These are listed below by organization involved. *See agenda - agenda (white paper)*

See agenda
PROBLEM 1. The Luminary program (with current schedules) will not be tested in flight before the Lunar Landing Mission.
IN PRESENTATION 2(A)

PROBLEM 2. Operational data control appears inadequate to support software development and verification, use of simulators and trainers, and mission planning and operations.
IN PRESENTATION 4

PROBLEM 3. The full two-way coordination of MSC divisions on software and hardware capabilities and interactions needs to be improved.
Suggest Kraft might cover in introduction.

PROBLEM 4. A plan is needed to utilize fully the various hybrid simulators in verifying the total crew/G & N hardware and software system as well as training the crew.
IN PRESENTATION 6 B.

PROBLEM 5. Efforts should be made to involve flight crew and flight controllers in review of procedures at an earlier date.
IN PRESENTATION 2 B.

PROBLEM 6. Improvement in coordination between hardware and software changes (how changes in one impact the other) seems needed. *A SPO ACTION!*

PROBLEM 7. Closer coordination between KSC and MSC for software testing at KSC seems required.
AWAIT TASK FORCE DIRECTION.

PROBLEM 8. The MSC has not independently verified the all digital simulations used in program verification.
STOKES ACTION.

The following action items were defined:

ACTION ITEM 4.1 The MSC to prepare a presentation on the Data Priority Task for the Software Task Force. Assigned to H. W. Tindall (MSC, Next Washington, D. C. Meeting)
ON PRESENTATION

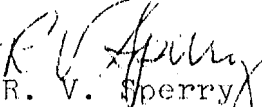
ACTION ITEM 4.2 The MSC to determine the need at this point for accuracy specifications which define necessary and sufficient Software performance. Assigned to J. P. Mayer (MSC, 2/16/68)

ACTION ITEM 4.3 The MSC to clarify the need for flight ropes (as opposed to test ropes or earlier mission flight ropes) at KSC for testing. Assigned to the ASPO. (MSC, 3/1/68)

ACTION ITEM 4.4 The MSC to review in detail development plan usage at MIT/IL with Appointed members of the Task Force. Assigned to J. C. Stokes, J. S. Martin, and R. B. Hanrahan. (2/16/68)

Problems in development of the Abort Guidance System software are not listed above. Such listing is deferred until after the meeting at TRW.


W. G. Heffron


R. V. Sperry

2014-WGH
2012-RVS -bjh

Attachment: List of Attendees

SOFTWARE TASK FORCE MEETING #4

January 16, 1968

ATTENDEES

<u>NAME</u>	<u>ORGANIZATION</u>
R. H. Battin	MIT/IL
A. I. Boysen, Jr.	Bellcomm, Inc.
L. R. Bush	Aerospace Corporation
D. R. Hagner	Bellcomm, Inc.
R. B. Hanrahan	IBM
W. G. Heffron	Bellcomm, Inc.
J. S. Martin	NASA/LaRC
J. P. Mayer	NASA/MSC
G. E. Mueller	NASA Headquarters
G. W. Pittman	TRW-Houston
L. G. Richard	NASA/MSFC
R. V. Sperry	Bellcomm, Inc.
K. F. <i>Steffan</i>	Aerospace Corporation
J. C. Stokes	NASA/MSC

BELLCOMM, INC.

DRAFT

SUBJECT: Minutes of Software Task
Force Meeting #4 - Case 310

FROM: W. G. Heffron
R. V. Sperry

DISTRIBUTION

Task Force Members

Messrs. R. H. Eutlin - MIT
A. P. Boyson, Jr. - Bellcomm/MAS
L. R. Bush - Aerospace Corporation
D. R. Wagner - Bellcomm/MLS
R. B. Harrahan - IBM
J. F. Mayer - MSC/FM
J. S. Martin - NASA/LARC
G. E. Mueller - NASA/M
G. W. Pittman - TRW
L. G. Richard - MSC/R-TO-DIR
R. V. Sperry - Bellcomm/MAS
K. P. Steffan - Aerospace Corporation

NASA

S. C. Phillips/MA

MSC

R. A. Gardiner/FC
J. C. Stokes/FS5

Bellcomm

W. C. Hittinger
T. D. Nehama
I. M. Ross
R. L. Wagner

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DRAFT

UNITED STATES GOVERNMENT

Memorandum

Sig Gibson

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

Kraft
File

Vou Gibson - file

TO : (Informal Distribution)

DATE: 18 JAN 1968

FROM : FM/Chief

68-FM-5

Have the answers to these questions in a briefing to the

MEETING #4

SUBJECT: Problem areas defined by the Apollo Guidance Software Task Force Meeting on January 16, 1968

What is to occur with MSC.

The following problem areas were defined at the January 16th meeting: *CDG*

1. Schedule.- Dr. Mueller felt that the Task Force should investigate the techniques of controlling schedules because of the importance of scheduling Apollo programs. Jim Martin was interested in the use of PERT in controlling schedules. This is not used at present but the program development plan takes its place. Jim was going to meet independently with Jim Stokes to look into this.

2. Problems relating to MSC organizational structure. -

1 Is the separation of the AGS and PNGCS organization at MSC an effective way to manage the software program? How is the interface controlled?

2 Should the MSC Flight Software Branch have a resident representative at MIT? ^{MSC} feels that they would have more efficient representation at MIT by having specialists and Flight Software Branch managers spend part of their time at MIT each week.

3 How is the utilization of the entire system integrated? (How is coordination effected between MSC and contractor organizations?) This is effected with Bill Tindall's new role as Chief of "Data Priority" in ASPO. In this role he has the necessary authority to integrate the work of all MSC directorates and contractors in determining the operational utilization of the systems.

4. How does Flight Software Branch get support from other divisions and directorates, and is it formalized?

5. Does Bill Tindall have sufficient full time support in his data priority job? Bill has four to six full time TRW personnel supporting him and he utilizes technical experts from all areas in the center.

6. How does KSC get inputs into the system? Ludy Richards was interested in this problem especially from the possible differences in testing philosophy.



7 What are the procedures for measuring impact of hardware or procedural changes on the software? Also, what are the procedures for informing software personnel of hardware changes which may affect the software?

8 Should all software personnel be consolidated in one area? This question referred to bringing together all of the people working on software, working in Guidance and Control Division, MPAD, Flight Control Division, and Flight Crew Support Division. It was pointed out that there are too many people working on software-related items to put them all in the same geographical area and that it was the Flight Software Branch's (and Bill Tindall's) job to coordinate and integrate the work of these people. Although in the case of the AGS it might be possible to consolidate the AGS and PNGCS software and managers.

9 Is the Change Control Board operating effectively? Is it too limited? Is it schedule-conscious? There were some questions here by Bellcomm representatives on whether too many changes were being approved by the Change Control Board and whether changes should be controlled to some extent before they get to the Board. It was the consensus of the task force that all changes should be brought to this Board for its decision and not just what was considered mandatory by the change proposer.

10 How is the RTCC spacecraft and launch vehicle software interface checked? What sort of integration tests are run? This included questions on such things as commands for targeting or updates and hardware or software interfaces.

11 What are the procedures that MSC uses to control operational data? How do we insure that the proper constants go into all software?

12 How do we insure that the actual procedures to be used by the astronauts are reviewed with the proper software personnel? In the past the actual astronaut checklist was considered a personally controlled checklist by the astronauts and was not thoroughly reviewed.

13 Is it possible to assign the actual astronaut crews for reviewing guidance software at an earlier date?

14 Do the astronaut crews have too much authority in making software changes?

15 Program control mechanization. - Is there anything that can be done to mechanize program control such as the use of PERT?

16 Can programs be defined to control dynamic erasable to insure that conflicts do not occur?

3. MIT organization.- Much of what was listed under MSC organization is also pertinent to MIT organization.

1 MIT CCB.- What work should be done on program implementation before reaching the Change Control Hoard? What is the process for controller work done in advance of CCB meetings?

2 Does MIT schedule effectively? Is the development plan a useful scheduling device? It was suggested that in order to show the usefulness of the development that the history of the SUNDISK program be compared with that of the SUNDANCE program.

3 In regard to SUNDISK changes the question arose as to the adequacy of the retesting of the SUNDISK program. It was inferred that there was no time for adequate retesting.

4 Does MIT have adequate manpower? It was stated that MIT has approximately 200 people assigned to the software and it was considered by both MIT and MSC to be adequate.

5 How does MIT control dynamic and static storage location?

4. Program verification.-

1 Why are ropes released at the end of level 4 test instead of level 5? How does this affect KSC test? It was brought out that MSFC had to release programs in a similar manner. Also, the question of the utilization of test ropes instead of program ropes was brought out. Is there a better way of using test ropes in KSC tests?

2 How do we know that the bit-by-bit digital simulation correctly simulates the onboard computer? Why can't we use the actual onboard computer for some of this testing? How can we compare bit-by-bit simulator results with actual computer results?

3 How do you confirm that what is loaded in the computer is the actual program that was tested?

4 What is the verification testing philosophy? How is MIT and MSC testing coordinated? Should we do more testing based on specific system failure analysis? Do we need specific specification test specifications?

5 How do we know that the MSC and MIT bit-by-bit simulators are compatible?

6 What are the plans for utilizing all of the hybrid simulators for program verification? Dr. Mueller indicated that the first priority for the crew trainers should be astronaut training and the second priority should be verification.

7 Bit-by-bit verification.- How do we insure that proper inputs are obtained from all responsible divisions for specifying bit-by-bit simulator runs and checking results?

8 How is the hardware software interface verified?

5. What computer reasonableness checks are made? What are they?

6. Should we specify performance and accuracy? What are the performance limits of the current system? For example, how close is close enough to assume that the rendezvous software is acceptable?

7. Documentation.- We need a program definition document including appropriate constants for each mission. Also, we need a standard procedures document (this is chapter 4 of the GSOP). We need a document defining the operational timeline. This document will come out of Bill Tindall's work.

8. A review should be made of all single point failures. No manual entry should bomb out the computer.

9. How do we insure that the lunar programs are adequately checked in flight before the lunar mission? What can be adequately verified on the ground versus in-flight and what is necessary for in-flight checkout? At the current time the luminary is not planned to be used before the lunar mission, This was questioned by Dr. Mueller.

9. A computer failure analysis should be made. Analysis should be made of possible computer failures which could be worked around in flight.

10. Program modularity.- How do individual changes in subroutines affect the complete program?

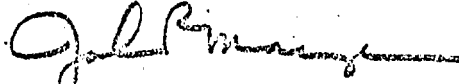
11. Is the program too complicated? Could we fly to the moon with half the computer capacity? Is there reason to initiate a backup simplified program in order to meet the lunar landing mission's schedule?

12. The AGS.- Many of the above comments are appropriate for the AGS as well as for the primary system.,

1 How stable is the AGS program? Are the changes now being proposed really necessary? Should we consider the AGS as strictly an abort system to be able to abort to lunar orbit safely and not consider it as complete backup guidance system which can effectively monitor the primary system?

13. How is the AGS independent verification system to be accomplished? Guidance and Control has assigned this task to the Flight Operations Directorate. FOD plans to do it under the same management as the PNGCS verification utilization, TRW Houston.

14. How are we assured that the AGS and PNGCS are completely compatible from both a hardware and software points of view?



John P. Mayer

Distribution:
FA/C. C. Kraft, Jr.
FS/L. C. Dunseith
J. C. Stokes

FM:JPM:dpf

UNITED STATES GOVERNMENT

Memorandum

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

TO : Informal Distribution

DATE: 26 JAN 1968

FROM : FM/Chief

68-FM-6

MEETINGS # 5 & 6

SUBJECT: Software Task Force Meetings at TRW, Los Angeles, January 24, 1968, and North American Rockwell Corporation, Downey, California, January 25, 1968

The following are some comments from my notes at the TRW and NR meetings:

TRW

Where does TRW get their operational constants for the AGS? They indicated CAEC but I do not really think they get them from Grumman.

The division of AGS and PNGCS management again was brought up. The necessity for the crew checklist to be looked at by TRW was indicated. TRW feels that they need to be more a part of the operation and be more fully consulted in the use of the AGS. (Dr. Mueller felt that this was a general problem throughout the Apollo program and that major subsystems contractors should be more involved in how their systems are operationally used.)

How is AGS testing criteria defined and what is the MSC role in defining test criteria?

Does MSC participate adequately in design reviews held at TRW? Is MIT participation needed?

The AGS system has specification requirements of 30 fps, 5 n. miles, and 5 n. miles at rendezvous. Where did these requirements come from?

Does the AGS adequately take care of RCS thrust? At the present time, TRW equations do not include the effects of RCS thrusting.

How are the system models for all simulators controlled? Do we have the same mathematical model and constants in effect? The answer is probably that no one simulator or program is exactly like another.

The single point failure in the AGS should be identified. This refers to program single point failures. Does the TRW AGS bit-by-bit simulator correctly simulate the control system using the simplified P and I specification model?

TRW does not use actual computers in any simulation, Grumman does this in their FCI lab. Perhaps TRW should have more input into Grumman tests or tie an actual computer into their simulation.



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Does the AGS launch program use fuel effectively? ~~Will~~ it target for a safe orbit, perhaps lower than nominally?

The need for a new navigational filter for the AGS was discussed. TRW indicated that the current filter could meet the specifications, But MSC and MIT had some doubts about the current filter being adequate for the mission. Real Evans and Norm Sears were to get together and discuss the necessity for a new filter and present the results to Dr. Mueller in about two or three weeks.

NR

The subject of the crew checklist versus the Apollo operations handbook came up again. North American gets copies of the checklist since they work with the crew in training exercises. The question was brought up again as to how the checklist was controlled and whether cognizant contractors signed off the checklist.

The entry monitor system was discussed and questions were raised about its compatibility with the primary entry guidance system and the variation in L/D's that could be accommodated.

During discussions about the North American simulator runs, it was brought out that all simulator runs were made with a shirt sleeve environment.

A formal test plan for the 101 spacecraft does not yet exist.

Jim Martin wanted to know why basic Apollo failure reporting systems could not be used for software. The North American people gave the impression that when Q.C. got involved, progress became very slow.

North American still considers the simulator a development facility. They were informed that NASA believes that the simulation facilities should be used more for software verification.

Again at North American the subject of involvement of major subsystems contractors in the approval cycle was brought up. It was asked whether the MCC link to the North American simulator utilized the remote site hardware.

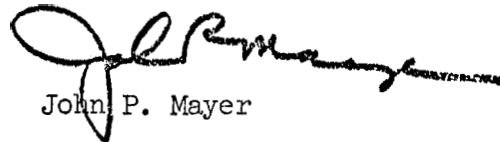
How do we insure compatibility between the different simulators both for input data and for mathematical models?

North American indicated that they had a shortage of experienced hybrid programmers and guidance systems experts. This was one reason why they were not able to get full utilization out of their simulator. One problem they have is the SDS 9300 digital computer Serial No. 1 and, therefore, not completely compatible with the other SDS 9300 computers.

When we were at North American they had just received SUNDISK Program No. 273. The program was bombing out the day we were there. Again the question was asked, why not stick with SUNDISK Program No. 267.

What configuration control of program tapes exist between MIT and North American?

Dick Battin indicated that he did not believe that there was enough time to adequately test SUNDISK Program No. 273.



John P. Mayer

Distribution:
FA/C. C. Kraft, Jr.
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J. C. Stokes

FM JPM:dpf

MINUTES

Apollo Guidance Software Task Force Review Team
Thursday, January 25, 1968

MEETING # 6

This meeting was held in the Apollo CSM Control Center, Building 1,
Space Division/North American Rockwell, Corp., Downey, California.

Attendees are as follows:

Dr. G. Mueller - NASA	R. Gardner - NASA, MSC
<u>J. S. Martin</u> - NASA, Langley	E. Rees - NASA
J. P. Mayer - NASA, MSC	J. P. McNamara - NR
L. G. Richard - NASA, MSC	D. D. Myers - NR
W. Gordon Heffron - Bellcom	W. Fouts - NR
Q. P. Boysen, Jr. - Bellcom	R. Kurtz - NR
D. R. Hagner - Bellcom	W. DeViney - NR
R. D. Sperry - Bellcom	J. Robertson - NR
L. R. Bush - Aerospace	R. Epple - NR
K. Steffan - Aerospace	G. T. Murphy - NR
Dr. R. Battin - MIT	J. Brown - NASA, RASPO
R. B. Hanrahan - IBM	D. Levine - NR
C. Pitman - TRW	
D. Gilbert - NASA, MSC	

The Chairman stated the purpose of the Teams visit to NR Space Division was to review the G&N simulation effort being conducted on the Apollo CSM program. W. Fouts, NR, presented a briefing (attached) which described the products of the current simulation program. The products are divided into three main categories: (a) design studies, (b) mission evaluation studies, and (c) hardware verification tests. Discussions concerning facilities, schedules, additional requirements and current problems were brought out during the briefing. A tape recording was taken of the complete meeting and is on file at NR.

Dr. Mueller stated that he understood the current contractual position of NR concerning the use of the simulation complex primarily as a developmental tool and to provide interface between the G&N and the Stabilization Control System. Dr. Mueller and team members requested that NR consider a more formal test program for this complex and present this approach to NASA, MSC for review.

The Team visited the simulation complex during the day.

INDEXING DATA

<u>DATE</u>	<u>OPR</u>	<u>#</u>	<u>I</u>	<u>PGM</u>	<u>SUBJECT</u>	<u>SIGNATOR</u>	<u>LOC</u>
01-25-68	NAR		R	01	(JTG)	NAR	067-21

Upon conclusion of the meeting Dale D. Myers, Apollo CSM Program Manager and Dr. Mueller summed up the meeting with the following action items for NR.

North American Rockwell should prepare a plan and submit a proposal to NASA, MSC for:

- a. ²⁰~~24~~ hour operation of the G&N evaluation complex
- b. Implement a formal test anomaly reporting and disposition system to cover all flight software used in the evaluation
- c. Provide for formal configuration certification of the vehicle functional configuration compatibility with flight software including tapes, crew checklists and the AOH.
- d. Incorporate detailed formal test plans for utilization of the complex for tape "cell" runs for each vehicle.
- e. Advise NASA of any additional facility requirements

Dr. Mueller added that NR should maintain test time data to show times that the complex is in operation as compared to down time. J. P. Mayer NASA, MSC, and Dr. Mueller discussed a possible increase in NR's participation in mission planning GOSS interface participation during pre-launch and mission operations, as well as possible participation in software CARR's. NR stated that this participation would be discussed with NASA, MSC.

Supplemental Agreement No. 300

UNITED STATES GOVERNMENT

Memorandum

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

TO : Informal Distribution

DATE: 6 FEB 1968

FROM : FM/Chief

68-FM-7

MEETING # 7

SUBJECT: Notes on Meeting of the Apollo Guidance Software Task Force at GAEC on February 3, 1968

Grumman Aircraft Engineering Corp.

The following comments are from my notes at the GAEC software task force meeting:

1. It was brought out that TRW does not participate in the testing of the AGS. Task force members and Grumman thought that TRW ought to be more involved.
2. Grumman does not have a formal software failure reporting system. Such a system should be instigated.
3. GAEC would like to have representatives from THW, MIT, and MSC present during testing.
4. The 7094 MOD II which is part of the hybrid *simulator* computer may be a limiting factor in the utilization of the computer. At the present time, the 7094 is used for other work at Grumman. The Full Mission Engineering Simulator (FMES) gets first priority on the 94. Currently the FMES is utilized about 9½ hours per day.
5. The 7094 MOD II used with the simulator is leased and the lease runs out in June although they have a three-month extension which can be used. Currently, GAEC planned to drop the 7094 in June and switch to the IBM 360 computers. Grumman technical people would prefer to stay with the 7094 for use with the hybrid simulator. They indicated that the change to 360's would be for economy only. It was discovered that Brock (CAD) is somehow involved in this switchover. (I talked to Brock when I returned and he indicated that he would like to keep a 94 at Grumman also but that he wanted to replace the leased computers with a NASA surplus 7094.) It was obvious to everyone present that Grumman should not attempt to convert their hybrid simulation to the 360 computers at this time.
6. In discussing how more effective utilization could be obtained of their hybrid computer, Grumman indicated that they had a problem in getting good hybrid personnel. This is the same indication that we got from North American. Grumman indicated that only 20 percent of the runs on the hybrid simulator could be called fully successful runs. The meaning of this 20 percent number is somewhat confusing; however, later they



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indicated that some of the runs used were for diagnostics. The 20 percent probably refers to the percentage of successful runs in a given formal test sequence.

7. The utilization of the FMES was supposed to phase out in June 1968 and, like the hybrid simulator at North American, it was originally intended to be used for hardware development work. This has changed now and Grumman has recently received a CCA for software validation report.

8. In regard to simulator utilization it was brought out that one shift is necessary for maintenance and that computer checkout is done on the prime shift before operational runs are made. This testing is made until 9:30 a.m.

9. In discussing the validity of the math model that Grumman uses, they indicated that they do not have a data book which documented their math model at this time but that they were going to put out such a book.

10. Grumman does not have their subsystems personnel participate in tests made on the FMES. Dr. Mueller instructed GAEC to insure that their subsystems personnel be involved in the FMES software validation and concur that their (subsystems people) equipment is being used correctly.

11. In regard to the LM-1 flight; it was found that Grumman did use an updated engine model which had a 3.5 second thrust buildup; however, that did not run any test other than nominal. They did not run three sigma dispersions.

12. It was indicated that Grumman should use the FMES for validating red lines and to find real, operational limits and not to confine their testing to three sigma variations.

13. It was obvious that we need a closer relationship between the GAEC FMES people and the MSC operational people.

14. Grumman prepares the AOH but have no formal sign off by TRW or MIT. They say that this is an MSC responsibility.

15. The checklist does not come back to GAEC. GAEC does review checklist and do comment informally. Normally the checklist is not used in Grumman simulations.

16. Grumman does not have a link with the Mission Control Center in Houston at this time. Why?

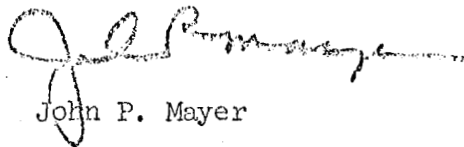
17. In discussing the FMES it was stated that it is almost impossible to keep the simulator up to date in that it does not always simulate accurately a specific LM. They try to achieve a functional similarity but not a direct cockpit similarity.

18. Grumman would like to get the operational trajectory sooner than they are currently issued since the reference trajectory does not always adequately reflect the current mission. Also they indicated that they need operational time lines sooner. They needed this for their mission modular data book activity. It wasn't apparent to me why they needed an exact time line for MMDB work. In regard to the operational trajectory, I believe that we can put out a revised reference trajectory before the operational trajectory which will suit their needs.
19. GAEC apparently does not like the DAP design - specifically in the area of the gimbal trim system. I believe that it is a software versus hardware problem in that they would rather change MIT software than their hardware.
20. In further discussions on utilization of the simulator, it was indicated that they could run two shifts but again adequate manning was the problem. Also, a lot of their equipment is rather old. Their analog computers are relatively old, being 7 years old REAC 500s. Also some of their flight hardware has been in use for almost two years. Some have exceeded their design lifetime.
21. In discussing the AGS tests run at GAEC, it was apparent that these tests were not coordinated with MPAD rendezvous personnel. It is apparent that both TRW and GAEC are forced to evaluate systems on unrealistic P & I specs which do not necessarily prove that the system can fly a real mission.
22. In discussing the flight schedule, Dr. Mueller again reiterated that we must be fully prepared to fly a lunar landing mission with LM-5 on Mission F. GAEC seemed unaware of this.
23. There is doubt that GAEC can continue with present test plans in addition to the new software validation requirements and meet current schedules. The present test schedule should be reviewed.
24. Again, the problem of needing an MIT program definition document sooner was brought out by GAEC. They indicated that it took much effort on their part to develop their simulator programs without adequately documented programmed equations. I think that all of us have agreed that MIT does not need flow charts to code the program but there are a lot of other people in the system that need adequate program documentation sooner for use in dispersion analysis, software validation, astronaut training, etc.
25. The next meeting was tentatively set up for February 9 in Washington. They wanted to get a report by Bill Tindall on his data priority activities at this meeting if possible. A second meeting was tentatively set

for KSC on February 14 to discuss KSC's inputs, and, in particular, their testing philosophy. One question that Ludy Richards continually brings up is why do we need actual mission ropes for KSC tests? Why aren't test ropes adequate?

26. Jim Martin will be coming to Houston on February 13 to discuss program control activities with Jim Stokes.

27. The 101 CARR was discussed somewhat at the end of the meeting. Dr. Mueller wanted to know on what basis we are buying off flight programs that are continually changing. I suggested that he talk directly with Mr. Kraft.



John P. Mayer

Distribution:

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J. C. Stokes

FM:JPM:dpf

MEETING # 8

1968

Notes of meeting of the AGSTF in Washington on February 9

IX J

The following comments are from my notes at the AGSTF meeting:

Has anyone at MSC checked the AMS simulator results (from the ^{intercept} representative simulation of the AGC) with the bit-by-bit simulator output?

Software tests are made on the AMS but so far they have been uncoordinated with MIT and ^{MSC} independent verification. Goeckler indicated that he had ~~had~~ some problems with the TRW independent verification tests. What were the problems?

Again the question came up as to why mission ropes are needed at KSC so early. The committee will meet at KSC on February 14 and will meet at MSC the following week. The committee wants Bill Tindall to discuss the Operational Systems Integration meetings ^("Data Priority") on the night of the MSC meeting.

How much useful time is obtained from the simulators? What measure is used to indicate efficiency of computer operations in simulations?

The flight checkout of the Luminary Program was again discussed. Dr. Mueller would like to know what portions of the program can and ought to be tested before the lunar landing mission. He would like the MSC written ^{position} portion on this. ~~Put~~ ^{It} this on the agenda for the MSC meeting. Clarence Pittman suggested that we make a postflight check of the outputs of the Apollo computer with that of the MSC bit-by-bit simulator for the LM-1 mission. Good idea.

The utilization of another contractor to independently program the Apollo lunar landing mission ^{as discussed} using a greatly simplified program ^{utilizing about} using perhaps half the memory and fewer ~~inner ups~~ ^{interrupts} were discussed.

Dr. Mueller gave an action item to the TRW and IBM representatives to investigate the feasibility and desirability of providing such a program. Dr. Mueller believes that the software is the ~~key~~ ^{key} item for the lunar landing mission. He is of the opinion that the lunar landing computer program is tremendously complicated and that MIT might not provide a reliable checked out program on schedule. He realizes that to use another simplified program provided by a different contractor would cost much money and cause a schedule slippage of at least one year. He still thinks it's worthwhile investigating the necessity for providing a simple program.

~~Although~~ I do not concur with Dr. Mueller's opinions since I believe we can ~~not~~ ^{however} provide a reliable program for the lunar landing mission, there does exist the possibility of ~~sooner or later~~ obtaining a Houston-based onboard software contractor ~~perhaps~~ for AAP. Such a task could be used as a mission familiarization task for a new contractor. Perhaps we can look into this since I feel that sooner or later we ~~will~~ ^{must} want a Houston-based onboard software contractor (which still could be MIT.)

Dr. Battin felt that we could better utilize the extra effort in making the current system work. He indicated that more IBM 360/75 time could be very effectively utilized at MIT.

At the MSC meeting, we need a detailed discussion of the software CCR's PCR's indicating the number of PCR's rejected as well as those accepted with some discussion of the reasons for making as many changes as were made on the 101 SUNDISK Program.

Software CCB. —

Several people have suggested that we have more formal software CCB meetings with all proposed changes being accepted no later than one week in advance of the next CCB meeting. Also, CCB minutes should be ^{issued} ~~read~~ promptly.

J. Maguire

W. J. Johnson

UNITED STATES GOVERNMENT

Memorandum

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

TO : Informal Distribution

DATE: 13 FEB 1968
68-FM-10

FROM : FM/Chief

MEETING #8

SUBJECT: Notes on Meeting of the Apollo Guidance Software Task Force in Washington on February 9, 1968

The following comments are from my notes at the Washington software task force meeting:

Has anyone at MSC checked the AMS simulator results (from the interpretive simulation of the AGC) with the bit-by-bit simulator output?

Software tests are made on the AMS but so far they have been uncoordinated with MIT and MSC independent verification. Goeckler indicated that he had some problems with the TRW independent verification tests. What were the problems?

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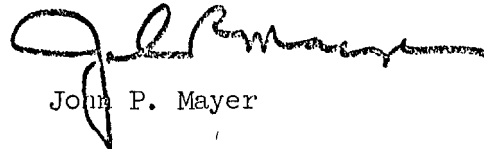
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