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MEMORANDUM FOR FILE

This memorandum has been prepared to distribute the Final Report of the Apollo Guidance Software Task Force.

The Final Report has been reviewed by Task Force members and signed by the Task Force's chairman, Dr. G. E. Mueller—Associate Administrator for Manned Space Flight.

2014-WGH-bjh

W. G. Heffron

Attachment
FINAL REPORT

APOLLO GUIDANCE SOFTWARE TASK FORCE

September 23, 1968

APPROVED

G. E. MUELLER
Chairman
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, USAF, 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 recommendations of the Task Force have already been acted upon. The following additional recommendations are made.

I. The difficulties in software development reflect the complexities of the Apollo missions 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 organizations 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, operational data, definition of software variables, was identified as a continuing problem in software development. The complexity 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 Program Standards for Physical Constants, Environmental Data and Coordinate Axes, amending 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.
   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

CHAIRMAN:

Dr. George E. Mueller
Associate Administrator for Manned Space Flight
National Aeronautics and Space Administration
600 Independence Avenue, S. W.
Washington, D. C. 20546

MEMBERS:

Mr. Kenneth F. Steffan
Head, Guidance Dynamics Department
Building A3-2093
Aerospace Corporation
P. O. Box 95085
Los Angeles, California 90049
(213) 648-6117

Dr. D. R. Hagner
Director, Apollo Applications Division
Bellcomm, Inc.
955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024
(202) 484-7654

Mr. James S. Martin, Jr
Head, Advanced Space Projects Office
(Unmanned)
Langley Research Center (Mail Stop 159)
National Aeronautics and Space Administration
Langley Station
Hampton, Virginia 23365
(703) 722-7961 - Ext. 3265

Mr. John P. Mayer
Chief, Mission Planning and Analysis Division (FM)
Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas 77058
(713) 483-3301
(Members Cont'd.)

Mr. Ludie G. Richard
Director, Technical Systems Office (R-TO-DIR)
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Huntsville, Alabama 35812
(204) 877-3760

Mr. A. P. Boysen, Jr.
Director, Mission Assignments Division
Bellcomm, Inc.
955 L'Enfant Plaza North, S. W.
Washington, D. C. 20024
(202) 484-7894

Mr. Leon R. Bush
Director, Flight Operations, MOL Project
Building 100-2061
Aerospace Corporation
P. O. Box 95085
Los Angeles, California 90049
(213) 648-5936

SUPPORTING MEMBERS:

Dr. Richard H. Battin
Associate Director
Instrumentation Laboratory
Massachusetts Institute of Technology
75 Cambridge Parkway (MS73)
Cambridge, Massachusetts 02142
(617) 864-6900 - Ext. 1295

Mr. Richard B. Hanrahan
RTCC Project Manager
International Business Machine Corporation
1322 Space Park Drive
Houston, Texas 77058
(713) 591-3300

Mr. Clarence W. Pittman
Manager, Mission Trajectory Control Program
TRW Systems Group (H1-2009)
Space Park Drive
Houston, Texas 77058
(713) 488-3530 - Ext. 2411
SECRETARIES:

Mr. Robert V. Sperry
Head, Guidance and Control Department
Bellcomm, Inc.
955 L'Enfant Plaza North, S. W.
Washington, D. C. 20024
(202) 484-7968

Mr. W. Gordon Heffron
Head, Guidance Program Analysis Department
Bellcomm, Inc.
955 L'Enfant Plaza North, S. W.
Washington, D. C. 20024
(2020 484-7970
ENCLOSURE 2

PLACES AND DATES OF TASK FORCE MEETINGS
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<td>1</td>
<td>Manned Spacecraft Center, Houston, Texas</td>
<td>Dec. 20, 1967</td>
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<td>Massachusetts Institute of Technology,</td>
<td>Jan. 5, 1968</td>
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<td></td>
<td>Cambridge, Mass.</td>
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<td>North American Rockwell Corporation,</td>
<td>Jan. 25, 1968</td>
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<td></td>
<td>Downey, California</td>
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<td>Grumman Aircraft Engineering Corporation,</td>
<td>Feb. 3, 1968</td>
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<td>Bethpage, N. Y.</td>
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<td>J. F. Kennedy Space Center,</td>
<td>Feb. 18, 1968</td>
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<td></td>
<td>Cape Kennedy, Florida</td>
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<td>Huntsville, Alabama</td>
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<td>11</td>
<td>Holiday Inn, Nassau Bay, Texas</td>
<td>March 1, 1968</td>
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<td>12</td>
<td>Manned Spacecraft Center, Houston, Texas</td>
<td>March 2&amp;3, 1968</td>
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<td>13</td>
<td>Manned Spacecraft Center, Houston, Texas</td>
<td>May 20, 1968</td>
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<td>14</td>
<td>Manned Spacecraft Center, Houston, Texas</td>
<td>July 12, 1968</td>
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