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SUBJECT: Distribution of the Final Report of the Apollo Guidance Software Task Force - Case 310

DATE: October 7, 1968

FROM: W. G. Heffron

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.

W. G. Heffron

2014-WGH-bjh

Attachment

FINAL REPORT

APOLLO GUIDANCE SOFTWARE TASK FORCE

September 23, 1968

APPROVED

G. E. 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, 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 compatability 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.

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

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ENCLOSURE 2

PLACES AND DATES OF TASK FORCE MEETINGS

APOLLO GUIDANCE SOFTWARE TASK FORCE MEETINGS

Meeting	Place	Date
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

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