NASA APOLLO LM/CM
# COMPUTER AND PROGRAMMING INFORMATION

TINDALLGRAMS

Memos by Howard Tindall of NASA describing development problems with the Command Module and Lunar Module computers and their programming. Tindall was NASA's watchdog for the MIT Instrumentation Laboratory's contract to develop the CM and LM computers and their programming.

UNITED STATES GOVERNMENT

Memorandum
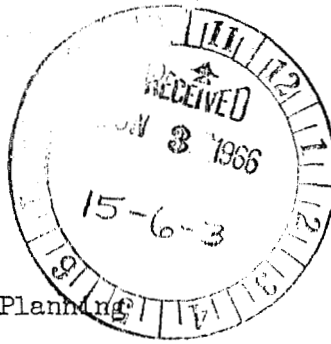
TO : See list below

DATE: MAY 3 1 1966

FROM : FM1/Assistant Chief, Mission Planning
and Analysis Division

66-FM1-68

SUBJECT: Apollo spacecraft computer program development newsletter

There are a number of us who feel that the computer programs for the
Apollo spacecraft will. soon become the most pacing item *for* the Apollo
flights. This is certainly likely to be the case for AS-207/208, by
which time spacecraft, and booster delivery and Cape operations are
likely to have become relatively routine, with the shots going pretty
much on schedule, and we working on the computer program development
will still be "sloshing through the mud." In an attempt to improve
this situation--1 hope improve--I have started to *go* to MIT a couple
of days every week to provide coordination between MIT and MSC. This
memorandum is the first of a series ,I will be dispatching to briefly
inform you on what is going on.

During the week of May 16, we put primary emphasis on management mat-
ters. During that week, MIT put into effect a new Computer Program
Development organization. Basically, what they have done is to put
Dr. Battin in charge of all computer programming, with four organiza-
tional units reporting to him, These units are headed by M E. Copps,
Mr. N. Sears, M J. Dahlen, and M ,J. Nevins. I still do not have
a clear understanding of how their work is broken out between the four
units; however, it is my understanding that M Copps has been made
responsible for program development; that is, the integration of the var-
ious program routines into a complete system, testing of that system
through release of the ropes. In addition, they indicated that they
have been authorized by MIT, and intend, to build up their program de-
velopment staff with the intention of carrying on program development
beyond AS-504. You will recall that there has been some hesitancy on
their part to augment their staff since they felt they would be phasing
out, but apparently they have reached a management decision that they
will not phase out; and, accordingly, they are willing to hire more
people, perhaps augmenting their staff by as many *as* fifty new people.,

By some stroke of luck, Lyn Dunseith and I took Dick Hanrahan of IBM
to MIT that week to give them a briefing of our Program Development
Plan, the management technique which we implemented about a year ago
with IBM for the MCC/RTCC, which has enabled us to know the current
status of the programs as they develop, to identify where our problem
areas were and to evaluate quickly and accurately whether program
changes could be made without schedule impact. Dick gave an excellent
informal briefing of this technique, which has served both IBM and
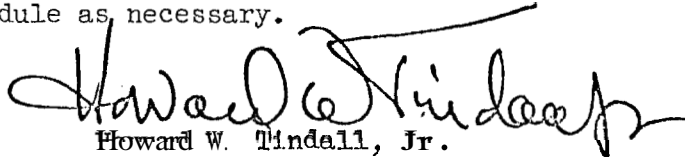
NASA wonderfully, and I hope and expect Mr Copps will draw heavily on this experience in setting up a similar system at MIT. We have offered every assistance to him in this matter.

I am still very concerned about unnecessary sophistication in the program and the effect of this "frosting on the cake" on schedule and storage. It is our intention to'go through the entire program, eliminating as much of this sort of thing as possible, I am talking about complete routines, such as "Computer Self-checks", as well as little features, such as including the third and fourth harmonics of the earth's oblateness and drag in programs for the lunar mission.

We also intend to maintain tight program control over MIT regarding modifications of the AS-504 program for the AS-207/208. It shall be based on the principle that change shall not be made unless absolutely mandatory. Mandatory items are defined as those without which the system absolutely will not work. It does not include such things as adding earth's oblateness effects into the lunar rendezvous guidance programs, even though failing to include these effects will cause propulsion fuel to be wasted due to guidance errors. We will find out what the cost of flying with a program like this is, and let you know. IT it is too expensive, we will make the necessary program changes, but only after readjusting the delivery schedule as necessary.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

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UNITED STATES GOVERNMENT

Memorandum

TU : See list below

DATE: JUN 13 1966

FROM : FM1/Deputy Chief, Mission Planning and
Analysis Division (MPAD)

66-FM1-75 1/4

SUBJECT: Apollo spacecraft computer programs--or, a bucket of worms

Well, I just got back from MIT with my weekly quota of new ulcers, which
I thought might interest you, We spent one day discussing the AS-204
situation, another on AS-501 and AS-5.02, and the third day primarily
on crew procedures associated with the LEM lunar rendezvous crew time-
line. I will give you my impression on each of these things, but first
I would like to let you know that Ed Copps is coming down on June 16
and 17 to give us a first cut at the overall schedule situation and the
status of the Program Development Plan which he has been putting together.
To help Ed in this urgent task, we have asked, and IBM (RTCC) has kindly
agreed, to send people experienced in this area up to MIT for the first
several days of the week to assist Ed and his people in the assembly
of this information we so urgently need. Ed briefly described the for-
mat of the Program Development Plan, which is obviously closely patterned
after IBM's and which seemed to me *to* be quite good if we really get it
working.

AS-204 Status:

Since this is the first time I have ever had anything to do with the
AS-204 program, I am sure my understanding of the situation is far from
perfect; however, perhaps this estimate of the status of the program
might cause you to get the true status from someone who does know if
I say something here that interests you.

According to Ed Copps, all fixed memory of the computer is filled; and,
in fact, it was necessary to take out about 500 words of the reentry
program associated with super-orbital entry in order to make it fit.
(Incidentally, this suggests we may have a problem on the AS-205 program
which is essentially the AS-204 program with about a 500-word routine
added in for support of an experiment unique to AS-205. I have asked A-
MIT to let us know at the earliest possible date if it is their opinion
that storage will preclude adding this program.)

A month or so ago some rather important guidance system capabilities
were deleted from our requirements in order to improve the schedule sit-
uation enough to allow a June 8 release by MIT of a program which could
support a nominal mission, the so-called "B release." This apparently
did not do the job. The program has just been compiled in a single sys-
tem and debugging is required in every area. In fact, according to

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		66-FM1-75			(Above)		

Ed Copps, not a single program sequence has been successfully run to completion yet. Thus, it was MIT's opinion that the program should not be released at this time. In fact, some of the programs--the 30 and 40 series--have not even been unit tested, although they have been included in the program assembly currently being used far system tests. This is certainly a very unsatisfactory situation.

MIT presented an abbreviated test plan for verification of this program, and it is my impression that the tests listed were to serve as part, if not all, of the formal verification and acceptance demonstration proposed by MIT. The list presented was not at all definitive but only described the runs in very general terms. The list consisted of twelve tests primarily designed to check capability of the program to support a nominal mission; it *was* estimated that these runs could be completed within four weeks. In addition, three other tests were identified associated with a variety of non-nominal- situations for which completion was estimated to be nine weeks.

Apparently Ed Copps does not expect the AS-204 'program test results to be formally documented, although Alex Kosmala says all this material will- be readily available on file. What a shame to have to accept a situation like that, but I suppose we have no real choice now.

It had been the intention to prepare the B release program for spacecraft systems tests to be carried out in the altitude: chamber at the Cape. As I noted before, it was desired on June 8. Aaron Cohen ascertained that June 23 was the very latest date this release could be made without causing a day-for-clay slip in the launch schedule. This date is based on the assumption that Raytheon will be able to manufacture the *ropes* in four weeks as opposed to the previous time allotment of six weeks.' Thus, you *see* it is evident that a program, flight-worthy in any sense, cannot be made avail-able in time for spacecraft. systems tests. In order to avoid the schedule slip, the Apollo Spacecraft Program Office (ASPO) decided to accept a program tape release for rope manufacture on June 23, using the best program assembly MIT has had up to that time.

The final flight tape must be released for rope: manufacture at some time between July 15 and August 8. Actual freezing of the flight program must be based not only on the Cape schedule but also must take into account flight crew training since it is important that the training be carried out with the same assembly as is flown. We have every expectation that the flight program we finally must accept will be of less than desirable quality. It will not have undergone sufficient verification tests and will very likely still contain program bugs. Following the flight program test release, extensive effort will be carried out to determine the limitations and inadequacies of the program in order that operational procedures may be established to work around them. Hopefully, none of these deficiencies will be *so* serious that tho flight may not be carried out on schedule.

It is our intention at MSC to maintain a close watch by locating our people at MIT most of the time such that we are immediately aware of the situation on a day-by-day basis. In addition, we intend to assist in whatever way possible in carrying out the test; program, doing such things as supplying information upon which test results may be compared, running analyses, etc. We also intend. to re-examine the overall rope production situation since in the next several months Raytheon will be requested to manufacture a large number of ropes to the extent that their capacity may be exceeded. I certainly don't want anyone to think that we feel the situation is any better than barely tolerable; on the other hand, as far as I can tell we are pretty well committed at this time with no alternative but to march along with our fingers crossed.

AS-501 Status:

Although the discussions on AS-501 started out being even more traumatic than AS-204, it looks like, maybe, we are going to come out of this one pretty well. Basically, we were told that the AS-501 and AS-502 program would be the AS-202 program with about 15% new formulation required. It was MIT's proposal that the entire program development task for the AS-501 and AS-502 programs be assigned to AC Electronics. Their first *estimate* was that the program tapes could be released for rope manufacture on about November 15, which is exactly three months too late. Rather an interesting proposal, I thought, since it is *so* obviously so unacceptable. After recovering from our complete shock, we started looking into the alternatives available to us and came upon one which made some of us wonder why we weren't doing it that way in the first place; i.e., just using the AS-202 program as is with only minor modifications, such as changing a few *of* the constants. Theoretically, this should not only put us on schedule, but maybe ahead of schedule.. An effort has been going on at MSC, under the leadership of Carl Huss, to determine just; what impact such a plan would have on the AS-501 and 502 flights. *So* far, as problems have been identified, acceptable solutions have generally been found; and it is my current impression thaf we shall be able to fly AS-501 and AS-502 using the AS-202 program with very little modification or impact on the mission objectives.

It appears that a somewhat greater burden will- be placed on the ground support for carrying out the AS-501 and 502 flights using the AS-202 program in this way. The most significant disadvantage is that certain alternate mission flexibilities and some launch abort capability must be given up. These capabilities would certainly be worthwhile if the schedule situation permitted. As soon as we are able to determine with some accuracy exactly what the situation is, this proposal will be carried to our management for the final decision. Incidentally, John Dahlen optimistically estimates that the GSOP for AS-501 will be available in about two weeks.

One most significant action was taken with regard to the concentric flight plan. It was the unanimous agreement of MSC and MIT personnel involved in this work that the concentric flight plan to be programmed for the Apollo guidance computer will be *as* it now exists in both the Rendezvous Analysis Branch and MIT. It is recognized that there are certain limitations to its use wherein under dispersed conditions it does not automatically produce a usable mission plan. However, through proper use of the input controls by the pilot--changing various parameters--it is possible to arrive at *a* solution if one is available. Accordingly, it was not felt *to* be fruitful nor would there appear to be time to permit further refinement of this formulation, and *so* we decided to proceed *as* noted with MSC accepting **full** responsibility for these deficiencies. Our task from now on, then, is to conduct sufficient analysis to identify these deficiencies and to provide onboard and ground backup procedures to take care of them.

Finally, if you are still with me, you hardy reader, let me tell you what I intend to put maximum effort on next. I am willing to bet that we are going to be told that MET is behind schedule on AS-207/208 and maybe AS-503 and AS-504. On the other hand, unless things change, we can probably expect to see the flight schedule accelerated, making the situation even worse. Although it is a pity to reduce the potential of this really sophisticated guidance system below its maximum, I see no other choice but to *go* through that program and ruthlessly cull out many of its refinements in order to simplify the program to its most austere form for those early Block II flights. The program paring must be done, I feel, solely for schedule reasons, which is really kind of weird when you think about how long the programs have been under development. It will mean that we fly to the moon with a system which does not minimize fuel expenditure nor provides the close guidance tolerances which are ultimately within its capability.

Once we have determined what can be removed of this nature, I **will** be sure to let you know, along with the costs--the waste of our precious propellants and increased miss distances. It will then be up to our management to decide whether these costs are acceptable or not. I have asked Norm Sears to prepare *a* first-cut at possible program deletions, based on this philosophy, and we will see if we can't add a few things to it when we go up there next week.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

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a

Memorandum

UNITED STATES GOVERNMENT

TO   : See list

FROM   : FMJ/Deputy Chief, Mission Planning and
             Analysis Division

SUBJECT: Another Apollo spacecraft computer program status report

DATE: JUL 1 1966

66-FM1-78

Jul 01 1966

This is another of my gripping reports on the status of the Apollo space-
craft computer programs and associated matters based on my weekly visit
to MIT on June 28 and 29.

AS-204: Debugging of the AS-204 program is reaching its final stages
with most of the operational sequences now working. It is anticipated
that the so-called "B release" tapes should do an adequate job of sup-
porting the spacecraft systems tests in the Cape altitude chamber. The
major capabilities not yet checked out and working in the "B release",
which is actually just the best assembly of this program existing at
4 p.m., June 30, and delivered to Raytheon for rope manufacture, are the
prethrust and thrust programs for the deorbit maneuver (other similar
programs are working and so it is expected these will be O.K. very soon)
and the auto positions of the optics. Many displays have not yet been
checked for accuracy yet either.

It is to be emphasized that the "B release" is certainly not flight-
worthy, and there is no intention of using it for that. In addition to
the fact that programming bugs still exist, it is virtually certain that,
with improper treatment, the program will bomb out; that is, excessive re-
strictions still exist as to how it must be used by the operator. The
system should be made more foolproof--if I may use that expression--before
it is committed to flight.

AS-205: As you know, every effort is being made to use the final
AS-204 program, as is, for the AS-205 flight, although it is highly
probable that certain changes will be forced upon us. Of course, this
is not to suggest that known program deficiencies--bugs--that are un-
covered after release of the flight tapes for AS-204 will not be cor-
rected. I am referring here to the addition of new capabilities. MIT
presented us with four documented recommendations for deletion of new
requirements which, if accepted by MSC, would permit using the AS-204
program. These changes are as follows:

   a. Side-force computations during the launch phase. It is antici-
pated that we will accept MIT's recommendation and delete this requirement.

   b. The capability for the crew to orient the spacecraft during
SPS maneuvers in either a heads-up or heads-down attitude. This requirement

was originally requested for. the AS-204 program but was rejected for schedule reasons with the implication that it would be added into the AS-205 program. Although final disposition must await discussion with interested MSC personnel., it is our current intention to accept MIT's recommendation and not provide this capability, unless it is mandatory for the mission.

    c. Modification of the program to do the S-16 experiment. This program provides the automatic control of spacecraft attitude to the fine degree of accuracy required to carry out this "trapped particles" experiment. It is anticipated to not be within the astronauts' capability to follow the rather complicated attitude profile manually, which means that failure to include this program would, in effect, eliminate the capability of doing this experiment;. Although MIT recommends deleting this entire requirement, they do offer an alternate proposal. They suggest that a duplicate set of AS-201 flight ropes be manufactured for AS-205 which would be used for all initial spacecraft testing. Then starting on August 1, *two* AS-201 programmers would start work on the program which would provide this new attitude control capability. Since the AS-204 program completely absorbs the available computer storage, it is necessary that some processor be eliminated if this change is to be made. MIT is recommending that the processor to be eliminated be a non-flight program used for prelaunch activity rather than reducing the in-flight capability of the guidance system. This certainly seems logical. to me, also. Therefore, it would be included in one of the six rope modules which is otherwise devoted entirely to preflight pad activity. Upon completion of the development of this .processor, a seventh rope would be manufactured to replace one of the six original ropes at some time in the midst of the preflight pad activity after the spacecraft tests requiring that rope have been completed. Unless the flight schedule slips, it would not be possible to supply the final version of the flight program--that is, all six rope modules in their final configuration--on schedule.

    If my understanding of the priority of the experiments is correct, I would guess that MIT's recommendation to delete this requirement must be rejected. and that we will follow their alternate proposal. The obvious disadvantages are that the ropes must be changed on the pad, and, *of* course, there is the expense of making an additional rope module.

    d. Changes to the telemetry down-link in support of the S-17 X-ray astronomy experiment. MIT, through direct conversations with the S-17 experimenter, have been led to the conclusion that it is possible to obtain the information required without change to the onboard computer program. It does require, however, that during the experiment the crew call up on their DSKY display the three quantities defining spacecraft attitude, which automatically results in this information being included in the downlink. Since this data may be asynchronous and for other reasons, it is

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probable that special *ground* programs must be developed for use in the ACR facility of the MCC to support the real time operations of the experimenter. We were told that somebody in the Flight Control Division is coordinating all of this MCC support, although I personally had never heard of it before and neither had Carl Huss.

In summary, it is anticipated that at least two of the four known requests for modification to the AS-204 program to support AS-205 shall be deleted, with a third (item "b" above) as a possible candidate. The fourth and biggest change will probably have to be made and, as noted above, will require the manufacture of an extra rope module *to* be assembled into the spacecraft during final prelaunch activities.

AS-206: MSC people most expert on the AS-206 mission, including Carl Huss of Mission Planning and Analysis Division and Dave Reed of the Flight Control Division, discussed the overall AS-206 program with the MIT people in an attempt to reduce MSC requirements to an absolute minimum for this program. The purpose of this was 'to assist to the maximum extent our overall effort to have this program available on schedule. Although the deletions made save in the order of $2\frac{1}{2}$ man-months of programming activity, which in itself is *a* worthwhile accomplishment, apparently we did not influence the pacing items of this program; and, as a result, the AS-206 schedule was not significantly improved. Obviously, further effort will be required. The discussions did have the benefit of reviewing the flight time-line in great detail, which brought to the surface a number of unresolved questions which were taken care of and which should *at* least permit MIT to proceed *as* quickly and efficiently as possible in their work. Although we did not satisfy our primary objective--that is, schedule improvement--on this occasion, the meeting was extremely valuable in these other respects.

AS-501: One entire day was spent discussing the AS-501 program, which is also slated for one-month late delivery. As reported in a previous note to you, our apparent best approach for the AS-501 and 502 programs was *to* use the AS-202 program with minimum modification. This is the course of action we have adopted and were thus able to improve the schedule from a three-month late delivery to a one-month late delivery. (Note: It is not entirely certain if a "one-month late delivery" is truly that since it is highly likely that the AS-202 program could be used for initial spacecraft; checkout at the Cape with very little loss of efficiency since these programs will be *so* similar.) Without going into detail on the program changes to the AS-202 program for use on AS-501, I would like to emphasize that the NASA/MSC has bend *so* far over backwards in an attempt to reduce requirements on the AS-701 program that we look like a double pretzel. We have eliminated almost all real time abort and alternate mission capability, an item which must be discussed in detail with our management. In addition to that, we 'have adopted a course of action which seriously perturbs other interfacing activities, which is annoying, to say the least, if not on the verge of being unacceptable. Use of the AS-202 program means that much *of* the work which has gone on for the RTCC

programs, the CCATS programs, and the Remote Site Data Processing programs, *goes* straight in the trash can. In effect, we have forced these activities, which were progressing in an orderly, businesslike manner, onto a crash basis to make them compatible with the onboard system. It is galling that the "good guys," who have really been doing the job right, are forced into the position of seeing their efforts go right down the drain, and then to be forced into a crash effort to make up for deficiencies in another system. On the other hand, there seems to be no choice in the matter for this particular mission.

AS-502: It was our intention to use the AS-501 program virtually intact for AS-502, however, there were some discussions which were completely over my head indicating that this may not be entirely possible, particularly associated with the large out-of-plane maneuvers and associated special platform alignments required in the AS-502 mission. Carl Huss intends to work this over as soon as possible to determine the true s'ituation in order to allow us to move on.

Other mission *programs* were not discussed on this visit, and *so* I don't have much of anything to report here.

Other matters: Shortage of programming development personnel continues to be the most pressing problem at MIT. However, steps are being taken at this time which seem, at least partially, effective and *so*, although we should remain concerned and alert, I *see* no useful action for us to take at this time. MIT has been successful in recruiting people from within MIT as well as obtaining offers of assistance, including short term, from several contractors which will *go* a long way toward relieving this serious situation. Steps are also being taken to clear the building of non-software oriented personnel to accommodate the bu-ild-up.

The major item which I am still concerned about and which is not, in *my* opinion, obtaining adequate attention is the Program Development Plan. I discussed this with MIT management, informing them, in *my* opinion, that the situation was still entirely unacceptable in all of these areas. If I don't see evidence of real improvement within the next couple of weeks, rest assured that ycu will hear about it--if you aren't deaf.

Howard W. Tindall, Jr.

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UNITED STATES GOVERNMENT

Memorandum

TO   : See list   DATE: JUL 2 1 1966

FROM : FM/Deputy Chief, Mission Planning and
          Analysis Division   66-FM1-95

SUBJECT: AS-204 computer program status

During the week of July 4, 1966, the prime and backup crews for the AS-204 mission attended briefings at MIT, which, among other things, led to their request that four changes be made in the spacecraft computer program for that mission. This request triggered off a considerable amount of activity which I would like to record here, indicating the final outcome of it all.

In discussing the overall AS-204 computer program situation with MIT people on July 14, 1966, I was told that a flight-worthy program would probably not exist on August 8, the date we had established for release of the flight program tape for rope manufacture. That is, according to the best MIT estimate, the program would still contain bugs and would not have satisfactorily completed its flight acceptance verification. They felt that delaying delivery of this program two weeks--that is, until August 22--was necessary to assure flight readiness. They also indicated that three of the four pilot requested program changes could be made with little or no impact during this period of time. These changes are as follows:

1. Choice of heads-up or heads-down spacecraft attitude during SPS maneuvers.

2. Display of latitude and longitude after completion of reentry guidance.

3. Display of the sensed retrograde maneuver--three ΔV's in the IMU platform coordinate system.

They estimated that the fourth change--providing a pilot choice of display during launch powered flight and immediately after insertion into orbit--would delay tape release an additional week beyond the August 22 date.

My personal view of this situation is somewhat different than MIT's. Considering our experience in the past, I question whether a truly flight-worthy program can be delivered on August 22, even without changes, and I'm certain that any attempt to make changes will only reduce our chances. The people who are currently carrying out the program checkout would have to make these changes, so obviously some of their effort must be diverted.
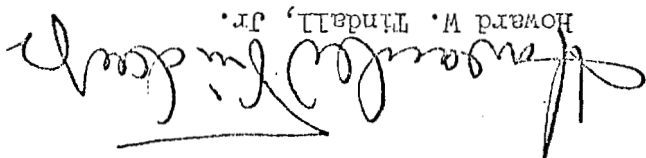
In addition to that, these program changes would certainly make further
program checkout necessary and would tend to nullify some of that work
which has already been carried out. Furthermore, although it would be
nice for the crew to have these additional capabilities, there does not
seem to be any technical justification for classifying them as mandatory.

Accordingly, it was my recommendation, supported by a number of other MSC
people, that none of the crew recommended changes be made in the AS-204
program. This recommendation was accepted by the G&N Subsystem Manager
and the Apollo Program Manager. And, that is how the situation stands
now.

One item of particular concern to the crew was the apparent lack of well
established crew procedures for making the GO NO-GO decision onboard the
spacecraft following S-IVB shutdown. Although the ground is primary for
this function, as it has been on past manned programs, it would certainly
be highly desirable to have this onboard capability, particularly recog-
nizing the somewhat poor ground monitoring and communications available
during Apollo launch. Furthermore, such a capability is very nearly
within our grasp, which makes it even more tantalizing. In reviewing
the status of the work going on in support of this onboard function, I
find that sticking to the current onboard displays will somewhat delay
availability of charts for the crew to use in this mission phase. Spe-
cifically, this work, which has been primarily directed toward develop-
ment of the RTCC/MSC capability, is now estimated to be within about four
weeks of completion and crew charts could have been made available at
about that time if V, $\dot{V}$, and h were displayed onboard the spacecraft.
However, since special charts will be needed for use with the parameters
to be displayed to the crew, an additional one or two weeks will be needed
for their preparation. Therefore, it is estimated that they will be avail-
able on about September 1.

In summary, MIT feels the earliest date a flight-ready program could be
delivered for AS-204 is about August 22, and MSC is authorizing delay of
the flight program tape release at least until that date. In order to
give greater assurance that the program will be flight-ready on that date,
no program changes are being authorized. In the absence of the most de-
sirable of these onboard computer program changes, specifically the pro-
vision of displays onboard the spacecraft for making a GO NO-GO decision
after launch booster shutdown, special charts must be prepared, which
will take about two weeks longer than if the changes were made, but should
be ready on about September 1.

Howard W. Tindall, Jr.

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OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum ·

TO : *See* list

DATE: SEP 2 0 1966

FROM : FM/Deputy Chief, Mission Planning and
Analysis Division

66-FM1-108

SUBJECT: Spacecraft computer program status for AS-501

This memorandum is to give *my* impression of what went on during the
meeting at MIT on September 12, 1966, regarding the AS-501/502 space-
craft guidance computer program. Primarily I would like to describe
the status of this program as we see it now.

We had previously been aiming for a release of the flight program for
rope manufacture on October 10. However, Dan Likely (MIT), who has
recently taken over management of this program, informed us that the
recent intense activity on the AS-204 program had completely saturated
the 1800 computers they all use for program development. As a result,
they had not been able to make a single computer run on the AS-501
program for a period of about two weeks. This had seriously disrupted
their planned program development and it was Dan's recommendation that
we delay release of this program until October 24, if at all possible.
Assuming adequate availability of the computers, Dan expects to finish
verification runs by October 10 and wishes to utilize the extra two
weeks for evaluating these tests to assure himself of flight readiness
prior to its release. Aaron Cohen checked with his associates who are
affected by this schedule and was able to negotiate this delay, which
we all felt *to* be highly desirable in order to avoid a repetition *of* the
AS-204. situation. In that case, you recall, we were forced to release
the program before some of the verification tests had even been run and
before the test results had been examined. It is probably worth noting
that Dan Likely appears to be taking over quickly and doing a very good
job. At least 1 certainly feel a great deal of confidence in his
ability to do this job right and on schedule. We intend to schedule a
Software Panel final status review on October 18, to be followed by a
presentation to all interested MSC personnel a week or *so* later.

AC Electronics was represented'at this meeting and reported that nine
of their people are now temporary residents at MIT, working exclusively
on the AS-501/502 AGC mission programming effort. In fact, they
constitute almost the entire work force at Likely's disposal. It is
my impression that they have come onboard and have become effective
very quickly. Part of their effort involves development of a simulation
of the Saturn V, which. is required. for program checkout. (Likely
identified this as one of the major remaining problem areas.)

AC also has a 21-man effort operating in Milwaukee. These people are
developing an independent verification facility for Block I programs

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which they hope to have operational about September 19. This includes an "automatic checkout system" capability which among other things is supposed to reconstruct the actual. program symbolically, thus allowing rapid and easy examination of the equations which have actually been programmed into the system. Considering all of the programming effort, both coding and verification, ahead' *of* us at MIT over the next several months, it seems essential to me that we make maximum use of this AC facility. 1 mean we must not use it in parallel with MIT's, but instead of MIT's, wherever possible. MIT has been directed to provide detailed test plans showing how these facilities will be used.

Most of the meeting was devoted to discussion of changes to the AS-202 program for AS-501 and selection of values for some of the flight para- meters. With a few minor exceptions, this all seems to be progressing very nicely.

We finally verified, to the limit *of* our ability, that the AS-501 pro- gram may be used without change for AS-502. MIT was requested to list possible problem areas, if any were recognized, particularly associated with fixed memory constants. Carl Huss was to call an MSC meeting to re-examine this subject from a trajectory standpoint on September 15. ('This has been done and as of today, we know of no reason these programs cannot be identical.)

That's about it for the AS-501 meeting. On Tuesday we discussed the Program Development Plans for AS-503 and AS-504 which I will report in another memorandum -- if I have the nerve.

                              Howard W. Tindall., **Jr**.

Addresses:
(See attached list)

66-FM1-108   2/2

UNITED STATES GOVERNMENT

Memorandum

TO   :   See list

FROM :   FM/Deputy Chief, Mission Planning & Analysis Division   67-FM1-24

SUBJECT: In which is described the Apollo spacecraft computer programs currently being developed

DATE: MAR 2 4 1967

MAR 24 1967

It is possible to take advantage of the stretchout of the Apollo flight schedule in the manner in which we develop the spacecraft computer programs at MIT. Although the flight schedules have not been fixed, it is evident that certain things can be done which will not only improve the quality and capability of the flight programs but should reduce the intensity of effort required of MIT to get them ready on time. It is the purpose of this memorandum to describe what we are planning to do in this area.

Within the month, the unmanned earth orbital LM program [formerly known as AS-206] should be released by MIT. After that, all program development work will be directly applicable to the main line lunar landing mission programs. As has been noted previously, only two spacecraft computer programs are operationally needed - one designed to support the needs of the command module on the lunar landing mission [formerly known as AS-504] and the other for the LM on that same mission. [Recall], these programs can also support all earth orbital development flights]. Every-one wanted to fly all Block II manned missions with these two programs, but it was evident about a year ago that the program development schedule [November 1967 release] was not consistent with the flight schedule for the earlier earth orbital development flights. As a result, we initiated development of two additional programs - one for the LM and one for the command module - for missions flown before the AS-504(!) programs were ready. They were formerly known, respectively, as AS-208 and AS-207 [later AS-205] and were scheduled for release in June of this year.

It now appears evident that the lunar landing LM program can be made available in time to support the first manned earth orbital LM mission, and as a result it should not be necessary for us to release a flight qualified LM program exclusively for that purpose. It's conceivable that these same remarks apply to the command module. However, in order to avoid taking the chance of pacing the Apollo 2 flight, it is our current intention to continue development of the command module program almost as it had been defined for AS-207 [later AS-205]. Certain modifications are contemplated which will result in its release occurring somewhat later than originally planned.

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Thus, it is our current intention to release, three flight qualified programs for rope manufacture - an earth orbital mission command module program, a lunar landing mission command module program and a lunar landing mission LM program. I would like to discuss each of these three individually in a little more depth.

Earth Orbital Mission Command Module Program:

Since this program will have the capability of supporting all earth orbital main line Apollo missions that have ever been discussed, its release, about the first of August, should effectively get the schedule completely off our backs for command module programs. Actually, I really don't expect that this program will be used for more than the first manned mission - Apollo 2 - since the lunar landing mission command module program will probably be available in time to support all of the rest of the flights. But, the point is, it could be used if necessary. Desirable modifications to the program, the implementation of which we were previously delaying until the lunar landing mission program, will probably be incorporated in this one. Final decision on these awaits MIT''s evaluation of their impact. Since it will no longer be necessary to deliver a LM program in the same time frame as this command module program, MIT's overall task should be somewhat easier to accomplish and the command module program should be of a higher quality.

In addition to supporting the Apollo 2 mission and, if necessary, any other earth orbital missions, this program has two other major uses. It will serve as a high quality component in the flight crew training facilities prior to release of the entire lunar landing mission program. It will also serve as an ideal point of departure for the development of the lunar landing mission program and the earth orbital AAP mission programs. The point here is that this program is just about an ideal subset of both of those more complex but entirely different programs and, having been carried through complete flight verification testing, will serve as an excellent foundation on which to add the unique programs required for those more sophisticated missions.

Lunar Landing Mission Command Module Program:

This program, which has lowest priority of the three, will probably be released about the first of the year. Earlier delivery may be possible if we twist MIT's tail, but I really see no point in it. However, it should be used for mission *support as* soon *as* it can be conveniently phased in, taking into account flight crew training as well *as* flight schedule. This might even be Apollo 2, of course.

What it consists of should not be affected by the mission reshuffling now going on.

67-FM1-24   2/3

<u>Lunar Landing Mission LM Program</u>:

Definition of this program should also be unaffected by current events, nor should its release schedule be much different; i.e., it should still be possible to complete it some time in November or December if such an early release turns out to be necesssry. Probably the most significant new factor influencing the development; of this program is associated with flight crew training. Whereas a flight qualified LM program for earth orbital missions was scheduled for release in June which could have been used for extensive flight crew training. This is no longer planned, but; the flight training requirement still *exists*. Accordingly, members of the Flight Software Branch are conferring with flight crew operations and program office personnel concerned with this activity in an effort to pin down flight crew training requirements. Specifically, we are trying to establish a schedule defining when certain components of the LM lunar landing program need to be operationel. Based on this sched- ule, we shall negotiate an over-all development plan with MIT with empha- sis placed on meeting this crew training schedule. Some slip in the final delivery date might be necessary for MIT to comply with this new program development constraint, provided that is acceptable from a flight schedule standpoint.

I guess I should point out that I really don't expect the development of these programs to be carried out much differently than had previously been planned. But slipping the flight schedule does provide some room to maneuver and has made it unnecessary to perform flight verification testing on a LM program exclusively for use on earth orbital missions.

To summarize the over-all situation regarding spacecraft computer program development, it is *my* feeling that no major problem exists any longer in this area. MIT has an organization and facilities geared up to handle the workload in an orderly, professional, unharried manner. High quality flight programs should. be available well ahead of their need. Revised program development plans are being prepared to provide you definitive milestones which we'll pass on as soon as they are available,

Your comments shall be received with relish.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

67-FM1-24   3/3

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : See list

DATE: MAY 1 7 1967
67-FM1-38

FROM : FM/Deputy Chief

SUBJECT: Reduced L/D presents a spacecraft computer program problem

This note is to help insure that the **word** gets around regarding reduced command module reentry L/D. MIT has heard rumors that the L/D may be reduced to a value of .25 and emphasized during our program development plan meeting that they are fairly certain the present spacecraft computer program formulation will not handle that. The current formulation is designed to handle a minimum L/D value of .30 and, although they **do** not know **how** far this limit can **be** extended, they feel certain major rework will be required for .25. This is not a new discovery. Our reentry experts in MPAD have been saying the same thing for some time.

Howard W. Tindall, Jr.

Addressees:
(see page attached)

"Dear "Bill".

It seems not right for using the
1/2 lift technique in the first place. If
you ask me you'd better get those cats
working on the right number ASAP.

CWT

5010-108

UNITED STATES GOVERNMENT

Memorandum

MAY 17 1967

TO   : See list

DATE: MAY 1 7 1967
67-FM1-39   1/2

FROM : FM/Deputy Chief

SUBJECT: A new spacecraft computer program development working philosophy
is taking shape

It's becoming evident that we are entering a new epoch regarding develop=
ment of spacecraft computer programs, and I thought I'd try to put my
impression relating to this into words and get them out in the open,

Until a few months ago, our most basic problem was getting the spacecraft
computer programs - and ultimately the flight ropes - completed in time
to support the official flight schedule. This presented such a challenge
to the people involved that intense reluctance was created to making
changes and, after a certain point, even correcting known deficiencies in
the programs. Where necessary, work around procedures were invented as
the only possible solution. Since the January accident the situation has
changed considerably in two ways. First *of* all, the flight schedule has
slipped to an extent that computer program development no longer paces
the flights in any way (including crew training and system tests) and,
secondly, the value of quality has become supreme. These things are most
clearly evident right now on LM-1 where it's almost unthinkable to fly
with any known deficiencies in the program - even those which would only
affect very low probability contingency situations - in spite of the fact
that the flight ropes have already been manufactured. I feel it's quite
likely the decision will be made to rework the LM-1 program and remanu-
facture ropes regardless of impact on any of MIT's program development
work, including delivery of the manned mission computer programs. In fact,
we have asked MIT to determine the extent of this across-the-board impact
assuming all of the known deficiencies in the LM-1 program are removed,
no matter how minor. Much more significant, however, is that without
doubt this situation is forcing us to adopt a new working philosophy
which should be recognized and included in all of our planning - program
development schedules, man loading, crew training, spacecraft systems
tests, etc. It is clear that, *as Ed* Copps puts it, program "shelf life"
is very short, That is, it is extremely unlikely we will ever fly with
ropes manufactured substantially in advance of the mission; instead of
releasing the flight program for rope manufacture at the earliest possible
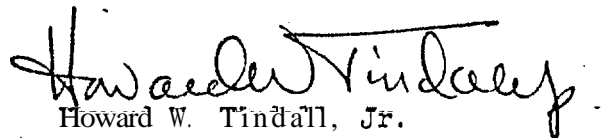date we should release it at the latest possible date.

The next question to be answered is - how far should the work on these assemblies proceed before being frozen (if you cull slush "frozen") and put on the shelf until some key milestone associated with spacecraft flight readiness? Should complete flight qualification Level 5 testing **be** carried out with the realization that changes will come along forcing us to revise the program and thus to repeat substantial portions of the **flight** verification? Or **should we** merely carry the program development through Level 4 testing, resulting in an assembly on the shelf which is **.bug** free as far *as* we know, but which has not been completely flight qualified? There are arguments for both positions. We have asked MIT to consider this subject - program development working philosophy - and to recommend their preference. We here at MSC will do the same and within a month will be prepared to adopt what appears to be the best over-all compromise. In any case, I'm sure **it will** force us to maintain a larger MIT staff and more program development facilities in order to be in a position to maintain and modify these programs until we finally release them. And we are less likely to have to' throw sets of ropes in the garbage can *so* often.

I'm not trying to flag this all out as a big problem area, It should certainly be easier to handle than our previous "schedule is king - anything is better than nothing" type of problem. But I'm sure what we do **will** have some fairly significant implications on everyone involved in the business of program development as well as the various users of their product and **I** thought **it** worthwhile to bring **it** to your attention.

Howard W. Tindall, Jr.

Addressees:
(see page attached)

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO   : See list

DATE: MAY 2 3 1967

67-FM-T-41

1/2

FROM   : FM/Deputy Chief

SUBJECT: Spacecraft computer program names

I used to think MIT was a little odd when it came to selecting names for the spacecraft; computer programs with all that weird preoccupation with the sun. But now I see they were right all the time and the rest of the world. is nuts - let's name the missions sequentially as they lift off the launch pad. Good grief, Charlie 'Brown! Having seen my error I'd like to apologize to our Bostonian friends for the abuse - and. worse - I used *to* heap upon them and publicly announce the end of *my* campaign to change.the program names. I think the old ones are just great and recommend you learn to recognize them if you're interested in this business.

There are only five names you need to remember; they are:

    a.   SOLRUM 55

        This contraction of the more familiar "Revision 55 of Solarium" was adopted for the AS-501/AS-502 program when it was released to Raytheon for rope manufacture. (The numerical part of the name is the number of the program assembly on which the final flight verification testing was carried out. This is a characteristic of all program names).

    b.   BURST 116

        Contracted from "Revision 116 of Sunburst", this is the name of the program for the unmanned LM mission we used to call AS-206.

    c.   SUNDISK

        Sundisk is the interim Command Module program now schedule? for release in July which could. be used for any earth orbital development flight. It probably won't ever be flown but it's availability will ensure that flight software does not pace the first manned mission. Dave Hoag suggested I could remember this name if I associated it with the shape of the command module - sort of a disk - and, by golly, it's worked for me.

    d.   COLOSSUS

        This is the name of the command module program designed to support the lunar landing mission as well as all development flights anyone has

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thought of, *so* far. According to Webster's New Collegiate Dictonary it also means (1)A statue of gigantic size; as, the Colossus of Rhodes, a statue of Apollo, about 120 feet high, made by Chares about 280 B.C. (2) Anything of gigantic size.

Pretty good except, I miss the Sun.

This program and Sundance (below) will undoubtedly be updated prior to rope manufacture for each mission, incorporating modifications and corrections as necessary. I expect these will be identified by different assembly numbers rather than completely new nemes.

e. <u>SUNDANCE</u>

You can remember the name *of* the LM program for all manned missions by associating dance with the LM's lovely legs - another of Dave's suggestions - and adding "Sun" as usual.

I'm serious, as usual.

Howard W. Tindall, Jr.

Addressees:
(see page attached)

67-FM-T-41   2/2

UNITED STATES GOVERNMENT

Memorandum

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

TO : *See* list below

DATE: OCT 17 1967
67-FM-T-83

OCT 17, 1967

1/2

FROM : FM/Deputy Chief

SUBJECT: Spscecraft computer program status

1. Here's another of my irregular updates on what's going on in the business of spacecraft computer program development.

2. SUNDISK, the earth orbital command module program, is essentially complete and, for all practical purposes, could be sent to Raytheon for rope manufacture whenever anyone wants to give the word. From all I have been able to determine, the quality of this program is very good and, perhaps, to balance some of the criticism of MIT, they should be commended for this. It provides the capability of doing all the things we specified over a year ago with numerous improvements added in along the way. (I am certain, however, changes will be made in it before flight; for the same sort of reasons we have re-made SUNBURST ropes twice.)

3. It is now evident that the lunar landing programs – COLOSSUS and LUMINARY – will riot be completed for quite a long time---certainly not for LM-3 and command module 103 as we had planned. This has forced us into the position of having to use SUNDISK on Command Module 103 and has made it necessary to develop an interim earth orbital program (SUN-DANCE) for use on LM-3 and LM-4.

4. At this time we are in the process *of* determining an accurate program development; schedule for these three programs at MIT as well as trying to identify the major problem areas in order to attack them on at least two fronts, namely, imple-ment improvements in the way the work is done and change the MIT organization to be compatible with them, I don't want to minimize the seriousness of this situation. We are in deep, serious yogurt!

5. One accomplishment of significance I would like to report is that we have recognized one way of substantially improving program delivery by making sure MIT has a precise, approved specification of the spacecraft computer programs required by MSC right now. Our recent SUNDANCE and COLOSSUS GSOP review and associated technical direction to MIT accomplished this to

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10-17-67	MSC	67-FM-T-83	1)		(Above)	T. TINDALL	
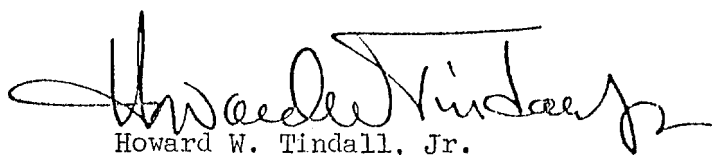
a large degree. However, there was one large area lacking definition and MSC approval, namely the change in the structure of the rendezvous programs which Flight Crew felt to be mandatory to substantially improve their operational procedures. In order to complete this program definition phase as quickly as possible, a team of MSC and MIT people spent the week of October 2 at MIT formulating and documenting all unresolved items in GSOP Chapter 4 format. I think this was accomplished very well in terms of both quality and speed resulting in a rough draft of the GSOP with MSC approval upon which MIT may prepare the final: GSOP and actually begin program design and coding immediately.

6. Thus, all three programs, SUNDANCE, LUMINARY, and COLOSSUS are now, in effect, covered by approved GSOP's and are under configuration control. That is, any changes must be handled through the standard change control procedures,

7. Unfortunately, it is highly probable that a similar exercise will eventually be necessary involving the Descent and possibly the Ascent portions of LUMINARY program once experience is obtained in their operation on the simulators at MIT and MSC. Mandatory changes to simplify crew procedures are likely to arise and the importance of crew evaluation of these processors at the earliest time can not be over emphasized. What; ever can be done by the Flight Crew Operations Directorate to provide a meaningful evaluation facility and. to utilize it for this purpose should be done for everybody's benefit.

Howard W. Tindall, Jr.

Addressees:
(see attached list)

United States Government
Memorandum

TO: See list below   DATE: OCT 18 **1967**

FROM: FM / Deputy Chief *(Howard W. Tindall, Jr.)*   67-FM-T-85   **1/2**

SUBJECT   Spacecraft computer program development improvements to be utilized by MIT *(Massachusetts Institute of Technology, Draper Labs)*

1. Just for the record, I would like to record a list of program development improvement ideas which MIT plans to incorporate. This list was gleaned from discussions by Ed Copps *(Edward M. Copps)*, Fred Martin *(Frederick H. Martin)*, and Alex Kosmala *(Albrecht L. Kosmala)* during the week of October 2, 1967.

   a) Much more complete program structure design work will be done prior to program integration. This includes more precise definition of the program module interfaces. And I suppose things like allotment of computer memory.

   b) Control of program constants will be *exercised* (?) to insure their accuracy and to avoid duplication from one procedure into another.

   c) In order to avoid the problem of erasable memory conflicts a panel is being established to manage the use of erasable memory.

   d) MIT proposes to initiate a series of periodic internal program design reviews.

   e) Approved program changes will be considered by MIT as they arrive from MSC *(Manned Spacecraft Center, Houston, Texas [a.k.a. JSC])* but will be added into the flight program assemblies in blocks periodically as opposed to randomly as in the past.

   f) Much tighter assembly control will be exercised with all program modifications being monitored and reviewed by a higher level of MIT management. Only those changes really necessary will be permitted. New assemblies will only be produced once a week as opposed to the much higher frequency hitherto.

   g) Associated with assembly control, specific processors will be "sealed internally in the assembly as they become operational as opposed to the current practice of putting the entire program under configuration control when all components are working.

h) It is my understanding that at present digital autopilots (DAP) are available for both the LM and command module. On the other hand, design improvements will probably be necessary on a fairly continuous basis. All modifications in the DAP's will be made and checked out in some program other than the current flight program assembly used by the rent of the program development personnel. Modified DAP's will only **be added to this working assembly when** they **are** running properly.

i) Much more coordination and **communication between** the various groups involved in software development **is essential. It is Martin's** intention **to** establish standing **committees** with **periodic** meetings for this purpose. _These_ meetings will. also be **used** for **consideration and** coordination of proposed changes.

j) Apparently, in the. past development of program **test** plans **has** been carried out by a **small group without** much assistance, advice or coordination with other interested **parties. Wider** participation in this effort both at MIT and MSC is **planned.**
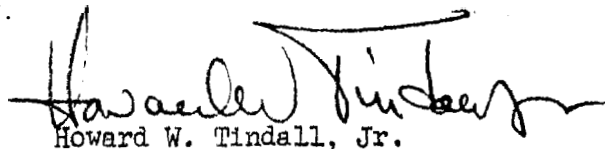
k) MIT has finally decided to utilize discrepancy reporting like _.we_ have requested for well over a year and which **has** recently proven to be of great value to them _in_ the latter stages of the **SUNDISK** development. They intehd to utilize this from the beginning on the remaining programs.

l) Associated with **the discrepancy** reporting, **MIT will** maintain an up-to-date operational constraint list. Obviously, one **way** in which discrepancies **may** be eliminated **is** by establishing work around procedures or operational constraints on program usage.

m) Steps are being taken to make sure that **as** problems are found and corrected in one major program these **same** flaws are corrected in the other programs (e.g., SUNDANCE and COLOSSUS).

n) Slow response in the exchange of data, particularly spacecraft characteristics, has delayed MIT previously. Steps are being taken at both MIT and MSC to provide faster response. When necessary, in lieu of answers from MSC, MIT proposes to state their assumptions and proceed ahead with program development to avoid **delays** of this type.

2. As you can _see,_ nothing particularly startling here but **I** believe everyone would agree those are all good things to do, that is, they should improve the quality of the program _itself_ and should certainly result in getting the job done faster. MIT has recently reorganized their personnel somewhat, hopefully in a way that will allow them to implement these ideas effectively.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

67-FM-T-85   2/2