LIMITED MEMORANDUM L-65

On the attached sheets are opinions regarding the ACDS System which I prepared on October 13 for use by Colonel Schenk

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October 13, 1952

As requested by the Air Force we are summarizing here our comments on the proposal that an immediate production contract be let for the "Air Defense Electronic Environment" being developed by the Rome Air Development Center, the University of Michigan, and the Laboratory for Electronics.

The justification for an immediate production contract appears to be based on two assumptions:

1. That the Rome-University of Michigan system is timed to meet the threat that the Air Force expects in 1955.

2. That time will be saved in achieving a working air defense system by immediate authorization of production without prior evaluation of

    a. Detailed block diagrams
    b. Physical design
    c. Components tests
    d. Prototype system.

We believe both assumptions 1 and 2 above are in error.

After studying the available information on the Rome-University of Michigan system we believe the following:

1. A. The system can not be available for extensive field operation in 1955 or 1956.

    We consider the time schedules given for the system as optimistic to the extent of estimating about one half the time which will actually be required. Also the time schedules as presented are misleading since they imply that completion of construction is coincident with operation; no time is included for installation, modification, and shakedown.

    In the attached table is the time schedule for the system as presented by Rome-University of Michigan. Even their schedule does not provide working systems before late 1956 or 1957. Also on the same sheet is our estimate of a more realistic schedule which differs, not so much by changing the times which they have estimated but instead by including those phases of the program which do not appear in the original schedule.

B. No time will be saved in getting working field systems by authorizing production before several more of the development steps have been evaluated.

This system is an order of magnitude more complex than anything the Air Force has thus far operated. Trained personnel will be in short supply. We believe that the time saved by omission of prototype testing will be more than lost in field modifications, debugging, and by the disorganization caused by extensive revision of complicated equipment at remote points. Modification of production equipment is difficult because of the inflexibility of production packaging. Furthermore, the system makes extensive use of a man-machine combination, and changes in the machine will necessitate retraining the thousands of operators and maintenance personnel.

C. Serious degradation of the air defense capability of the country will result from wholesale installation of untried, complex equipment.

The foundation of the abbreviated Rome-Michigan time schedule for the system is the:

1. elimination of a prototype model
2. full scale production before test and evaluation of a complete system
3. immediate installation of field systems coincident with first experience in using such systems
4. modification in the field of those defects that appear in the design.

This system will be more complex than any previous comparable assembly of equipment in either military or civilian experience. All previous experience indicates a minimum of a year to find the defects in the first installation and to bring the first installation up to useful operation. In the meantime the proposed schedule implies that other installations will be progressing. These can be expected to confuse the operation of the old system without at first contributing to an air defense.

The system should be expected to reduce our defensive capability in the critical years 1956 and 1957 if installed according to the schedule proposed by Rome and University of Michigan.

D. The idea of placing a production order as a "calculated risk" shows no prospect of saving time and will limit the future freedom of the Air Force in making a decision based on evaluation tests.

If produced according to the proposed time schedule, there will ensue delays during debugging, and the desperate hope that simple modifications will correct deficiencies. The confusion of such a period will probably postpone consideration and ultimate availability of any system which in the meantime has followed an orderly development to a successful system.

E. Any air defense equipment which the Air Force wishes to have in widespread, useful operation in 1955 must be complete in operating system form in 1952.

The two years of 1953 and 1954 are a very short lead time for production, installation and training for use of equipment in the many locations which the Air Force must operate. A realistic schedule for a 1955 system does not allow additional experimental or design time.

F. The following more minor comments can be made about the Rome-University of Michigan proposal:

1. Only a broad outline of the system and its suggested performance have been presented. This takes little time or effort compared to the lengthy design and testing phases which are scarcely started.

2. The complexity of the equipment has been greatly minimized in the presentation. Tube counts appear low for the items given and many items of equipment seem not to appear in the tabulation.

3. The report UMM-100 on the proposed system seems to be more a listing of the problems in air defense rather than a statement of how these problems are to be solved. The unavailability of technical detail in reports, presentation, discussions and laboratory visits leads to the conclusion that the physical nature of the system is not sufficiently established to justify the degree of confidence in time schedules or estimates of equipment complexity necessary for action on a production contract.

4. There appears a tendency to promise anything the Air Force, as customer, would like, independent of engineering realities.

The following comparisons between the Rome-University of Michigan proposal and the system being developed by Project Lincoln should be pointed out:

1. The development of the system at the University of Michigan is in a very early stage. The present status of that equipment seems to be lagging about two years behind the comparable period in the Project Lincoln development. They can benefit by the intervening development carried on throughout the country and should be able to close this two-year gap. If so, they can be expected to complete system design and production at about the same time as the Project Lincoln Whirlwind II centralized digital system. We feel that there is little or no chance of their making up the present time lag and producing a successful system earlier. Development of the Rome-University of Michigan system should, however, be continued without abatement until the validity of these opinions has been tested.

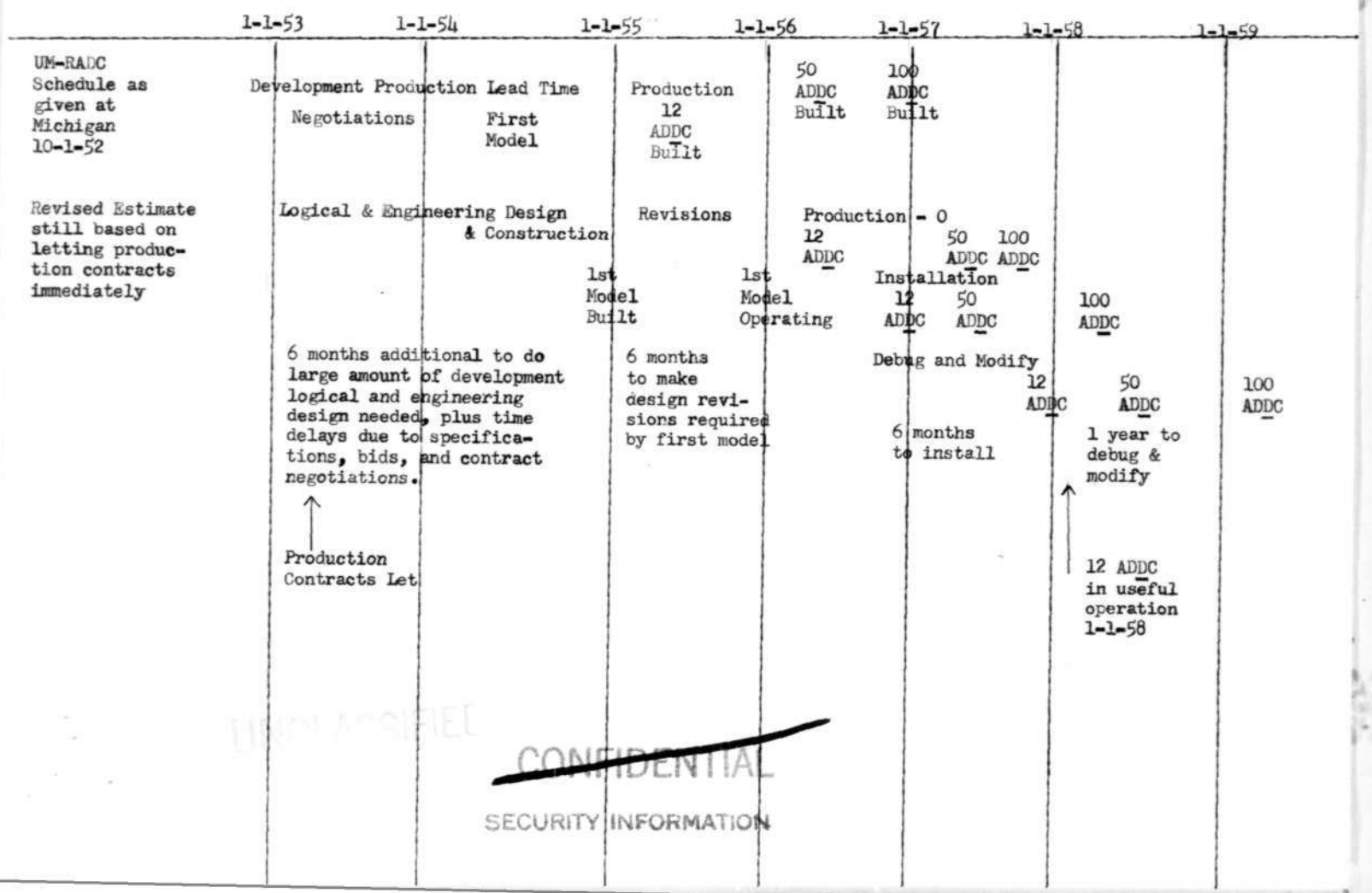
2. For use in 1955, the Air Force should expect to obtain only that equipment which is now in experimental operation and for which complete designs exist.

The Project Lincoln equipment already demonstrated at Truro and other equipment in a similar state of completion can be considered. To be realistic, Air Force requirements must recognize the essential lead time in electronic equipment just as in aircraft.

3. There is no essential difference in the complexity of the Rome-University of Michigan system and that being developed by Project Lincoln. There is no basis for distinguishing between systems on the basis of man-years or calendar time to complete development. If this is correct, the ultimate decision can be based only on a comparison of performance.

attch: Time Schedule

TIME SCHEDULE



The ACDS can be criticized on the following grounds:

1. What it is said to accomplish
2. The means used to accomplish the ends desired
   a. technical
   b. human or operational
3. The present status of the development and the probability that the finished device will resemble the presently available plans.

1. ACDS is said to do better all those functions which are now carried on by ADC. The following remarks apply:

The procedures and doctrines of ADC are those developed by trial and error over the last 10 years in the absence of any information handling apparatus at all. It is by no means to be assumed, that had ACDS existed during the past, that doctrines, procedures, and tasks would be as they are now. New weapons bring new tactics, viz the present development of infantry tactics around helicopters and airlift generally; more anciently the effects of the battle of Crecy in which the long-bowmen defeated the knights in armor.

Consequently the installation of this very complicated display equipment to carry out precisely those functions which are now carried on without it, can only be greeted with dismay if little flexibility of operations is allowed by that equipment.

Moreover this equipment will be used for a long time to come. New weapons will be available against new threats. New tactics and strategies and operational doctrines as yet unimagined will be needed. Flexible equipment is needed to allow the development of these.

Consequently the equipment developed should be complicated (if complication is needed) from the technical point of view only. If its complexity implies rigidity of operational structure and also complexity of operational structure, then its utility will be vastly diminished. In this respect the ACDS falls far short of yielding in return for its complexity, a good gain to air defense. Indeed it is as though the internal combustion engine had been applied to make mechanical horses rather than automobiles; the ornithopter has never been successful.

2a. The following remarks pertain to the technical means currently advocated for the implementation of ACDS.

Although it is alleged that ACDS can be put into production now the Michigan report UMM 100 is vague on many points, such as : the ground to ground data link; the choice of an analogue vs a digital store; the correction for earth's curvature if AN/TSA-8 equipment is not used.

In other cases the job has been made unnecessarily complicated and hard to develop by virtue of the philosophy adapted, for instance:

1. The PPI sweeps have to accurate to + 1/2 mile because of the netting requirements (this was not necessary in the original British design). Such sweeps will be most difficult to keep in calibration.

2. The nature of the system makes it difficult to operate with radars of different P.R.F.'s. Thus different radars require different display characteristics; and a type of gap-filler integration device of dubious performance. It is believed that when this has been completely examined in all its ramifications (by suitable experiments) still more complicated devices will be required to be added to ACDS.

3. For various reasons the original British device as tested at NRL (ref NRL report) has been complicated by the proposed installation of rate-aided tracking. The possibility of getting satisfactory velocity information from this kind of device using manual tracking of real radar echoes was cogently criticized by personnel of AIL (page 19, Minutes of RADC Air Defense Conference, July 8, 9, 10, 1952).

4. More comment on the techniques proposed would be made if the descriptions of these were available. They are not available in either Minutes of RADC Air Defense Conference, July 8, 9, 10, 1952, or in UMM-100.

5. It is stated (page 3, para 15, UMM-100) that "Furthermore, the air defense system proposed in this report can accept any satisfactory digital computing system which may be developed in the next few years for integrated control of all weapon types, both manned and unmanned."

This may be true, but if fully automatic digital computers were installed, the retention of any of the ACDS equipment, digital or otherwise, would only impair their performance and would be a complete waste.

2b. Operational

The use of ACDS presupposes a large body of highly trained men. It is unclear that men of such degree of training and innate skill will ever be available. Indeed the proponents of the system are themselves apparently in doubt on this point, for instance: (page 10, para 3 Minutes of RADC Air Defense Conference, July 8, 9, 10, 1952)

> "Human operators will be used where decision functions are to be performed.
>
> The requisite equipment will supply the human operators with precisely the data which they require. Then, using SOP's, they can perform their functions rapidly and efficiently."

Now if these men are to make decisions precisely what is meant by S.O.P? If it is accepted that the digital version of ACDS is what will be attempted then one concludes from this that information is to be transmitted, stored and calculated upon digitally by ACDS. Nevertheless automatic digital

computers which do these functions are precluded because of the urgent need for equipment.

> "The Senior Director capability test program and equipment were also shown to the visitors. A simulated raid as it might appear to a weapons assigner was shown on a vertical board and on manual tote boards. The vertical board has moving light spots to indicate enemy targets. Enemy raids of up to 250 planes are simulated and three types of weapons are available to the defense. Tests already run using this equipment indicate that: (1) the Senior Director is saturated in a situation of this type, even if he has relatively few decisions to make; (2) training and various types of graphical aids are important factors in improving performances; and (3) use of a simple rule (SOP) in making assignments can be as effective as human ingenuity, but that the simple rule will not give the best possible results." (p. 35, Minutes of RADC Air Defense Conference, July 8, 9, 10, 1952)

This seems to say that a man can do the job if it is made so simple that a machine could do it anyhow. Lincoln is not certain of the validity of these Michigan findings--they are quoted here to illustrate the lack of concreteness of understanding of the problems of ACDS by its own proponents.

Further, it has been stated by the Laboratory for Electronics

> "The ACDS is a new man-machine combination and, as such, it should be subjected to analysis by human engineers. Unfortunately, human engineering as a science is not yet developed to a point where hypothecated systems can be analyzed; however, human engineers are very successful at evaluating actual equipment. So much of the performance of the ACDS predicates a satisfactory man-machine combination that validation of the assumptions is most important."
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> - LFE Report 791-F on Final Engineering Report on CDS, December 1951.

Lincoln is in complete agreement with this. No reports on ACDS which have come to our attention indicated that these validations have been accomplished.

It is the belief of Lincoln that there is a high probability that tests on a complete ACDS functioning ADDC with the postulated 100 track capability, will show that the human beings in the system cannot operate it.

Indeed this is apparently recognized in UMM-100 (pages 93-94) as still being a problem, for it states:

"The importance of adequate operational test equipment cannot be over-emphasized. Successful operation of the Air Defense System depends upon the highly coordinated activity of a large number of men and machines under a large variety of operational conditions. A basic level of training activity will naturally result from day-to-day operations involving the handling of routine civil and military air operations. This will be augmented by training programs aimed at particular components and operators. There is an additional need to make the integrated system operate under realistically simulated and controlled battle conditions. It is the latter problem which, because of its complexity, is of primary concern."

It is a stated advantage of ACDS that every man in the system can get out of store whatever information he wants whenever he wants it. Now how does he know when to want this information? Is this done by an S.O.P.? If so, precisely what is the S.O.P.?

The identity officer has 3 PPI's and a code reading tube plus no less than 18 operational controls (knobs and switches). These are presumably in addition to technical controls such as focus, gain, etc. How fast can one man work this if he can work it at all?

The chief controller is similarly burdened with presentations and controls.

The development status of ACDS on the basis of UMM-100 July 9 report and visit to University of Michigan is very incomplete. Essentially no trials have been performed with real A/C but only with simulators. Simulation is useful to test the technical performance of any system; it tells next to nothing about how it will operate in reality.

Moreover even what has been tested with simulators are only a few of the consoles -- none of the heart of the system exists in any form, and insufficient of the control consoles are available to test the system as an operating organization. It is unlikely that the system will be far enough along even to test in 1953.

There is a considerable probability that if production contracts were let now on this system, a complete waste of money would be the result.

It is even more probable that even if production did start in 1955, that about 3 years of debugging and extensive modification would ensue before any useful operational value to ADC would be obtained. In this connection, note that the 6b MTI, recognized as bad in 1950, will have a new MTI available 1954. The FPS-3 antenna, known to be poor in 1950 -- will have new "Big kit" modification due as part of ACDS program.

Finally, note the following quotes from pages 42 and 43 of UMM-100:

> "In the ADCC, extensive use is made of electronic switching circuits and electronic storage elements. This is especially true in such units as the buffer and temporary storages, the MID integrator, and the coordinate converters. Design work is in progress on these circuits at WRRC. About six months additional design and test effort is required to obtain reliable and flexible basic circuits."

This we would interpret as meaning that from 6 to 12 months must yet ensue before breadboard models of some of the most basic parts of ACDS have been prepared. How then can production be considered now? Note that "logical design" means block diagrams and algebra.

SYSTEMS COMPARISON

	QUICK FIX	ACDS	WWII SYSTEM
Radars used	Present long range sets plus "interfix" addition of gap fillers using SDV	Modified long range radars (FPS-3) plus new gap fillers Restrictions on pulse repetition rate.	All radars available without pulse repetition rate restrictions.
Netting	By superposition of facsimile transmitted "clear-board" pictures at ADCC.	Optical superposition using Vidicon, graphicon and cameras.	Auto-digital parallax correction to provide overall display.
Tracking	Manual position tracking; manual dead-reckoning.	Manual rate-aided tracking includes dead-reckoning.	Automatic, smoothed velocity includes dead-reckoning.
Height Finding	V-beam or nodding beam	V-beam or nodding beam	V-beam, nodding beam plus new method on new small radars.
Slant range correction	none	none	Automatic Digital.
Interceptor guidance	Manual guidance as at present; could use Raggazini computer.	Manual or Ragazzini computer	Automatically calculated by WWII for collision mid-course guidance and procedure final turn. Direction of attack (tail, beam, head-on, etc.) can be selected by operator.
Return to Base	manual	manual or by a computer not yet designed	Auto-vectoring to entry of final approach system Manual monitoring
Gross Weapon Assignment of squadrons to raids	Manual at combat center (ADCC)	Manual at Combat Center (ADCC)	Automatic with manual override at combat center
Individual weapons Assignment One weapon to one target	Manual at ADDC	Manual at ADDC	Automatic with manual override at combat center

SYSTEMS COMPARISON

	QUICK FIX	ACDS	WWII SYSTEM
Initiation of tracking	Manual	Manual	Automatic or manual or part automatic and part manual
Estimated Track Capacity	40-50	100	500
New operating and maintenance personnel (estimated)	40/div	1230/division	250/division
Estimated Tube Count (tubes added) (exclusive of present equipment)	800/div	32,000 not including stand-by equipments	30,000 including stand-by equipments (3 computers, etc.)
Weapons Control	At ADDC as at present	At ADDC using special computers for each of F 102, F 99, etc.	At combat center in order to avoid problems of overlap and hand-over same computer for all weapons
Delivery date of first prod. model	1953	1955 but prod. equipments must then be modified (estimated by L.F.E., etc.)	1956 - no modifications expected these having been accomplished on dev. model.
Installation time/div estimated	6 months	3 years (est. by Lincoln) (First division, including installation, and modifications)	6 months
Training period required to regain efficiency of present system (est.)	2 weeks	one year	one month
Low alt radar data link bandwidth need	1.6 kilocycles phone-	4.5 megacycles (raw video as of Sept. 29, 1952 (UMM-100)	1.6 kilocycles (phone-line)