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REPORT ON MIDAS

by

DDR&E AD HOC GROUP

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REPORT ON MIDAS

DDR&E MIDAS AD HOC GROUP

I. SUMMARY

MIDAS is a development program to obtain a system of orbiting satellites for the infrared detection of enemy ICBMs in their launch phase.

The important things to be said about the MIDAS program are:

1. Although MIDAS can probably be made effective against large high radiance liquid-fueled rockets, it is not certain that this is so because of important gaps in our knowledge concerning target and background radiation.
2. MIDAS in its present design is probably not effective against smaller solid-fueled missiles such as MINUTEMAN and POLARIS, and there is doubt that it can be made effective against them in the next few years.
3. The existing design of MIDAS is so complicated that it probably cannot be made reliable enough to warrant deployment.
4. The emphasis on an early operational date contributed to neglect of the basic research and technology on which the success of the program depended.

In spite of the above criticisms, there are very good reasons for the continuation of the MIDAS program:

1. There are significant military and political needs which would be met by an operational MIDAS system.
2. A great deal of highly useful technology has already come, and will continue to come, from the MIDAS development program.
3. It is probably possible to adopt a redesigned "simplified" MIDAS which would have a good chance of meeting the reliability goals. This design would have some loss in coverage for the system, but presumably would be effective against mass liquid-fueled ICBM attacks.

Certain steps should be taken at once in the MIDAS program:

1. The operational prototype (Series 4) should be immediately cancelled.
2. There should be a drastic reorientation of the existing design in the direction of a simplified MIDAS having much greater prospects of adequate reliability. The Series 4X design, while a step in this direction, is probably not adequate. At a later date a decision can be made concerning deployment (perhaps 12-18 months).
3. In parallel with the above, an active study and development effort on advanced payloads and capabilities (e.g., against

lower-radiance-fuel ICBMs, POLARIS and MINUTEMAN type missiles) should be carried on, which can be fed into the flight test program as their development warrants. Consideration of alternate frequency bands and geometries should be included.

4. To support the above, there should be a supporting basic research and measurements program, not managed by the MIDAS program office, but closely coordinated with the program.

5. No operational date should be specified until the R&D program has developed to a point where full confidence in capabilities, schedules and costs are in hand. It is felt that this decision is at least 1-2 years away, which implies an operational MIDAS no sooner than about 1966 and probably later.

Elaboration of these statements and recommendations will be found in succeeding sections of this report.

II. WHAT IS MIDAS?

MIDAS is conceived as a system of orbiting satellites each equipped with an infrared sensory device designed to detect enemy ICBMs in their launch phase and thus provide the earliest possible warning of enemy attack. The approximate 15-25 minutes of warning provided by BMEWS would be extended to about 20-33 minutes by MIDAS in the case of the most probable attack (over the north polar regions).

The present system is designed to use eight MIDAS satellites in carefully controlled (orbit adjust feature) polar orbits, four in each of two orthogonal planes, at about 2,000 n.m. altitude. Three ground readout stations are planned, one each in Alaska, Greenland and the United Kingdom. There is a very high probability that at least one satellite will always be within line-of-sight of all of the USSR and at least one readout station. Detection and transmission to the readout station is immediate, i.e., there is no storage of the signal in the satellite. From the readout stations, the data is transmitted over communication lines (BMEWS circuits will be utilized) to a central computing and display center located in the United States, and thence to the ultimate users (SAC, NORAD, etc.).

The MIDAS satellite itself consists of an AGENA vehicle put into orbit by an ATLAS booster.

In order to reduce the radiation from the earth and low clouds to a level such that targets can be discerned against this "background", only a narrow band of the infrared spectrum will be utilized. This band has been deliberately chosen in the atmospheric absorption region so that, at satellite altitude, little or no radiation from the earth or low clouds is received. (This also means that the ICBM itself cannot be detected until it climbs above the sensible atmosphere.) There still remains, however, the problem of high clouds and thunderheads (above 40,000 feet, say) which contribute significant radiation above the atmosphere and would hence be seen by the MIDAS satellite and perhaps be confused with real ICBM targets.

The problem of attaining adequate reliability has led to consideration of a simplified version of the existing design called Series 4X. It would have the following features:

No orbit adjust.

No commands.

Greatly simplified attitude control system.

Static instead of rotating solar arrays.

Reduction in parts from about 22,000 to 16,000.

Reduction in weight of about 200 pounds (3200 to 3000).

Since the orbit adjust feature would be eliminated, the system would require about 12 satellites in uncontrolled polar orbits. This increase of about four satellites is required to assure reasonable coverage from uncontrolled orbits, but even so, these gaps in coverage are greater than with 8 satellites in controlled orbits. Primarily for this reason the random orbit system is less attractive to the Air Force.

III. THE USES OF MIDAS

There is one very important argument favoring a deployed MIDAS system: that in conjunction with BMEWS it will greatly raise the credibility to be attached to early warning of a mass north polar ICBM raid. There are also various subsidiary arguments which, when added together, comprise a significant total.

The military significance of early warning applies primarily to the alerting of the manned bomber force. These bombers now constitute our primary retaliatory capability, and although they will decline in relative importance as our ICBMs grow in number, they will still be of great significance over the next decade. SAC plans provide that even as late as 1967 its bombers will number about 800 and will carry twice as many megatons as our then deployed ICBMs. Hence the value of early warning, while diminishing somewhat in importance with time, will still remain very high over the foreseeable future.

The disadvantages of flushing our bombers unnecessarily are very great. This is not only because of the loss in confidence which would affect future decisions, but also because for a period of hours after a false scramble the aircraft are incapacitated, due to the necessity for refueling and again attaining a state of readiness. They would therefore be subject to a devastating follow-on missile attack. Furthermore, a SAC flush on false information could itself be a trigger to war, by causing the enemy to flush his SAC in turn, leading to a highly unstable situation. For these reasons, the SAC commander must regard such a step with the utmost gravity.

Flushing SAC in increments at levels proportional to the size of the attack also should be considered. Here again credibility is a major factor, but in addition to the knowledge that an enemy attack has been launched, SAC needs as accurate an estimate as possible of its magnitude.

These considerations point up the importance of the following conclusion:

1. Since MIDAS and BMEWS constitute two completely independent means of obtaining early warning of mass raids, together they will substantially raise the confidence level of early warning from that provided by BMEWS alone. BMEWS warning comes from land-based radars; MIDAS warning from satellites carrying infrared sensors. Spoofing effective against one will not work against the other. Their respective warnings are separated in time; hence a reasonable correlation can be made between an early MIDAS warning and a later BMEWS alarm which would greatly increase the confidence level that an enemy attack was indeed under way. Furthermore, the magnitude of the attack can be gauged with greater accuracy by combining BMEWS and MIDAS information.

In addition to the above, the following additional considerations concerning the alerting of our bomber force may be advanced.

✓2. Increased warning time. MIDAS will probably give about 5 - 8 minutes more warning time than the approximate 10 - 25 minutes given by BMEWS. SAC is confident that it can launch all of its ground alert aircraft (66% of the total force after 1964) in 15 minutes after early warning (assuming 2 minutes decision time). On this basis alone, the contribution by MIDAS to the number of aircraft saved is marginal. On the other hand, the contribution which MIDAS could make in keeping the decision time to a minimum might be very important, and this in turn could result in a much larger number of aircraft preserved from destruction.

✓3. Increased coverage. There are at least three classes of missile threats on which MIDAS might give warning unobtainable by BMEWS.

a. Missiles which underfly or overfly BMEWS. There is doubt that missiles will overfly BMEWS both because of the difficulty of concealing the tankage (large radar cross-section), and because of the increased warning time which the enemy suffers if detection does take place (longer times of flight). Underflying BMEWS is feasible but only with a loss in accuracy. If we consider underflying a real threat, we should probably install BMEWS gap fillers, which could be done with relative certainty of performance and on a much shorter time-scale (say 2 years).

b. Submairne-launched missiles. The most important point to note here is that the existing MIDAS design probably cannot detect SLBMs, due to their lower IR output and shorter burn time, and that there is considerable doubt that the state of the art will advance enough in the next few years to permit it to do so, even with substantial redesign. A second point is that means exist to provide warning (such as radars deployed around our coasts), which can be implemented with greater certainty and on a shorter time-scale than MIDAS. On the other hand, if MIDAS were deployed for other reasons, and if the state of the art permits, MIDAS might give as a by-product perhaps 5 - 14 minutes of early warning against SLBMs. There is considerable doubt that the enemy would use a large submarine fleet for an initial attack, due to the strategic warning which such a fleet might give.

✓ c. Extended range ballistic missiles (ERBMs). The USSR undoubtedly has the capability to attack us from the south and to thus avoid BMEWS detection. In such a case MIDAS could be very effective in providing us with early warning. Arguments against this possibility are the loss in accuracy to the enemy compared to short-route ICBMs (a factor of 4 or 5); the decrease in payload which the enemy must accept (about 50% reduction); and, most important, the possibility that we might obtain, by one or another means, greatly increased early warning time (two hours minimum). Furthermore, if we are really concerned at this possibility, other means of early warning, such as south-looking radars, could be installed at less cost and sooner than MIDAS.

Summing up coverage arguments, none of them seem too impressive in themselves, but taken all together they seem to constitute a significant by-product if deployment of MIDAS were decided upon for other reasons. The following argument applying to a "graded response" situation may be made.

4. "Graded response" capability. In addition to providing some estimate of the magnitude of the attack (mentioned above), MIDAS may be capable of identifying the sites from which

launchings are made, particularly if our intelligence has located them in advance. Hence, if we postulate that the enemy makes an initial, less than all-out, attack, holding back a substantial number of his missiles, our ability through MIDAS to know those launch sites which were not utilized on the first attack could conceivably be quite valuable. We might, for example, concentrate our retaliatory fire on the remaining unused sites. In general, MIDAS may give added flexibility and permit a better assessment of alternative choices in at present unknown situations.

Considerations of our "command and control" survivability may be advanced.

5. Command and control. Intensive study is currently being given to the survivability of our civilian and military leadership under a massive attack, so that a considered and mature response of a controlled nature can be made. Doctrine will be developed to cover various conceivable circumstances. This doctrine will not depend on early warning, since early warning may not be forthcoming. Hence, command and control considerations are not a primary argument for a deployed MIDAS. On the other hand, there is a valid line of reasoning which says that advance warning from MIDAS

could, under some circumstances, help insure the survival of some of the higher echelons of our leadership and thus provide a more responsible and constitutional basis for any decision concerning our response to an attack. Furthermore, by providing an answer to the question "Which country attacked us?" MIDAS might make an invaluable contribution in an unstable world situation when countries other than the US and the USSR possess nuclear bombs and missiles.

In addition to the above reasons which apply primarily to our military response to a ballistic missile attack, there are other reasons of a non-military nature favoring MIDAS deployment.

✓ 6. Arms control environment. Assuming a future world situation in which there has been negotiated an international agreement to limit the number of ICBM launchings, a MIDAS type system would provide a valuable means of providing a monitoring mechanism of all ICBM launchings, including our own. It should be noted that other means of detection exist (radar, acoustic, intelligence, etc.), but that MIDAS would provide a valuable supplement to them.

✓ 7. Civil defense. The question arises as to whether a deployed MIDAS supplementing BMEWS can save a substantial number of civilian lives in the case of a ballistic missile attack.

Those civilians near the immediate impact point cannot be protected. Those civilians removed far enough from the impact point so that only fall-out is a menace to them do not need the relatively few minutes of extra warning time provided by MIDAS, since fall-out danger comes many minutes or hours after an attack. There still remain those people in the suburban areas who might conceivably survive low level blast and radiation if a few extra minutes of warning were provided.

✓ 8. Intelligence. A deployed MIDAS type system might provide very valuable peace-time information on the characteristics of new Soviet missiles, such as burn-time, thrust, type of fuel, launch sites, etc.

✓ 9. Finally, an important argument favoring the MIDAS research and development program (not its deployment), is that it provides an invaluable space research tool. Solution to the problems of infrared technology and satellite long-life-in-orbit will provide great benefits to our military and scientific space programs. As an example, no other military satellite program has yet had to face up to the problems of reliability confronting MIDAS. For example, its value to communication satellite programs, which have similar problems, is obvious.

IV. HISTORICAL REVIEW OF PROGRAM

Early studies established that a MIDAS system was probably technically feasible and by mid-1958 the Air Force had established a going program, then called Subsystem G of Weapon System 117L, at Lockheed. The program was transferred to ARPA upon the establishment of that agency and in November 1958 ARPA Order 38-58 established the MIDAS program, essentially as a continuation of the Air Force program.

In February 1959 a MIDAS Development Plan submitted by the Air Force to ARPA called for a 10-shot R&D program over the period November 1959 to May 1961 and an initial operational capability in July 1961. After a review by a scientific committee headed by Dr. Purcell, which concluded the technique was technically feasible, the program was approved in March 1959.

Even at this time it was realized that two principal problem areas were:

1. The infrared detection problem.
2. Reliability.

The first of these centers around the character and amount of infrared radiation to be expected from targets, and the difficulties to be expected in distinguishing the target in the presence of background radiation from clouds. Very little was known concerning both targets and background radiation.

The second problem of reliability is based on the fact that a very long life in orbit is required, of the order of a year, to make the system economically feasible; and that such a life is orders of magnitude beyond what has previously been attempted in satellite technology.

It is also possible to see, in retrospect, that other, unknown problems of the space environment in which MIDAS was planned to operate would doubtless arise. An example, not appreciated then, is the effect of the Van Allen radiation belt on solar cells and infrared detectors.

What is obvious with hindsight was the necessity of establishing an intensive measurements program on target and background radiation, a greatly increased effort on reliability, an increased number of R&D launches, and a relaxation of the operational date.

A few high-altitude balloon flights to measure background radiation were made in the period June-December 1959. There was a complete dependence on other programs to obtain target radiation data (only now, in the Fall of 1961, are these data on our own targets becoming reliable). In the meantime, the program went forward, gathering momentum in funding, facilities, personnel, and public visibility as it went.

Late in 1959 the program was reassigned to the Air Force. A new development plan was issued by the Air Force in January 1960, which slipped the operational date to April 1963.

Two MIDAS launchings were attempted from AMR in the Spring of 1960. The first failed to attain orbit. The second attained orbit successfully, but little or no useful infrared data was obtained.

In the meantime, the Air Force, for various reasons (including pressure from its critics) began to attack its basic problems. Two additional DISCOVERER launches (known as RM-1 and RM-2) were authorized in June 1960, whose primary purpose was to measure background radiation. A separate study on reliability by an outside contractor had estimated the life on orbit of a MIDAS satellite at about two weeks, and the contractor himself estimated it as only a little over a month. Hence, additional funds were reprogrammed into MIDAS to attain greater reliability -- but the improvement was aimed at the existing design, and not at the drastic simplification which seemed to be required.

A PSAC Committee under Dr. Panofsky reviewed MIDAS in the Fall of 1960 and concluded that the MIDAS concept was basically sound, and that the program should proceed, but that more infrared measurements were needed, that more R&D flights than ten would be necessary, and that a greatly increased effort on simplification and reliability would be required. The PSAC Committee also recommended consideration of a random orbit system and consideration of other parts of the spectral band.

In December 1960 and February 1961, the RM-1 and RM-2 DISCOVERER launches were launched. Successful orbits were obtained and although each had trouble with attitude stability, some useful IR information was obtained.

A U-2 aircraft was obtained for the purpose of making additional background measurements, and flights were made in the period January-June 1961. Useful information was secured.

In March 1961, the Air Force recognized the necessity of additional R&D launches by issuing a new development plan calling for 24-27 shots. The operational date was now set for January 1964.

In July 1961 MIDAS III was launched and performed successfully on a few orbits but signals were lost after this, due to a power failure.

The last MIDAS launching (October 1961) attained orbit but was unstable in attitude (probably due to an ATLAS guidance failure). Most of the equipment performed successfully for about a week at which time a power failure occurred. Much data were secured, but it is too early to assess their value. Published reports that it detected a TITAN launch were erroneous (whether it did or not is unknown at this time).

Because of a conflict with SAMOS scheduling, the next launching has been delayed indefinitely.

In the meantime, increasing concern about reliability has led to a contractor study on a "simplified" MIDAS (referred to above as "Series 4X"). This proposal has not as yet been accepted by the Air Force. Adoption of this system may be justified but would result in much time, effort and funds put into the present design being wasted.

The operational date is now stated to be July 1964 if an immediate go-ahead is given.

One can see from the above resume a general pattern of optimistic operational dates, slippages, basic (and relatively cheap) supporting programs in the measurements area added as afterthoughts, and only a gradual realization of the importance of the reliability of the system and what will be necessary to achieve it. Indeed, the last is still not universally agreed to.

Along with the history of the program itself, there has been an evolution in time of the military requirements. When MIDAS was first conceived and scheduled for operational use in 1961, almost all of our striking force was in our large bombers. Maximum warning time is vital to bombers, both because they are soft, and because they can be launched on warning and recalled if necessary. As time advances and as more and more of our strike force is shifted to missiles, which, once launched, are launched irrevocably, the advantages of reliable early warning decreases. It is not conceivable, for example, that our 1967 MINUTEMAN missiles would be launched on MIDAS warning alone. Hence, the importance of MIDAS tends to decrease with time in its function of alerting our strike force. There still remains the fact that bombers will constitute a substantial part of our strategic forces in the foreseeable future, and that MIDAS might also perform important functions in alerting our civilian and military leadership, in helping to assess a graded attack, in civil defense, in an arms control environment, and in intelligence.

V. STATUS, SCHEDULE AND FUNDING OF PRESENT PROGRAM

The present 24-launch program is divided into five series:

	Series 1	Series 2	Series 3	Series 4	Series 5
Launch Site	AMR	PMR	PMR	PMR	PMR
No. of Launches	2	3	4	12	3
Orbit - nm	261	2000	2000	2000	2000
Latitude	Low	Polar	Polar	Polar	Polar
Power	Battery	Solar	Solar	Solar	Nuclear
Agena Propulsion	Single-burn	Dual	Dual	Dual	Dual
Orbit Adjust	No	No	Yes	Yes	Yes
Data Link	VHF	VHF	VHF-UHF	UHF	UHF
Payload	1st gen.	2nd gen.	3rd gen.	Prod. Prototype	Advanced
Dates	Feb-May 61	Jul-Dec 61	Mar Sept 62	Oct62-Jun63	Oct-Dec 63

The Air Force estimate to support this development program is set forth below:

	Millions - RDT&E
FY 1960 and prior	76.1
FY 1961	107.4
FY 1962	201.0
FY 1963	185.0
FY 1964	90.0
FY 1965	50.0
	709.0

In addition, $30-$40 million Military Construction Funds will be required.

Recent guidance furnished to the Air Force by the Secretary reduced the FY 1963 funding to $100 million.

Allowing for slippages and overruns, about $1 billion will be required for this program if it continues as is, of which about one-third has been spent.

VI. PROBLEMS OF MIDAS.

There exists a series of major technical problems associated with the MIDAS concept of sufficient severity to make it impossible to predict with confidence that an operationally significant version of MIDAS can be obtained within the next decade. These problems are:

- ✓ False Targets (due primarily to sunlight reflected from high clouds)
- ✓ Missed Targets (due primarily to possible enemy use of fuels with lower luminosity than LOX RP1)
- ✓ Equipment Reliability

In addition to the major technical problems of MIDAS, there are operational issues which must be assessed. Among the more significant are:

- ✓ Assurance of Continuity of Coverage
- ✓ Vulnerability to Enemy Countermeasures
- ✓ Integration with BMEWS and other systems

While the operational problems appear less formidable than the technical ones, they will largely determine the system cost (if the technical problems, including equipment reliability, can be essentially overcome).

Detection of Targets and Rejection of Cloud Background.

There are no physical limits to the sensitivity of detectors (suitable for incorporation in satellite systems) which would prevent detection of ICBMs and IRBMs from great range. As an example, the relatively low intensity ATLAS sustainer engine radiates about 5 MW in the portion of the infrared band to which the widely used lead sulphide detector is sensitive. This radiant flux could be detected from beyond 10,000 nautical miles by an IR search instrument similar to those presently planned for MIDAS.

Serious difficulties, however, are presented by the fact that MIDAS (as presently planned) looks down on missile targets, and therefore scans a background made up of the earth and its atmosphere. The IR instrument cell alluded to in the previous paragraph would collect about 10 times more energy from the night time surface of the earth within its field of view than it would from the ATLAS sustainer engine at the same range. Thus, changes of the topography from point to point could simulate actual missiles. When sunlit the situation is much worse. A sunlit snow field in the field of view would look 1,000 times as bright as the ATLAS sustainer.

To overcome this severe background problem, the MIDAS design makes use of a narrow band of radiation (2.65 - 2.8 microns) to which the earth's atmosphere is highly opaque, due to absorption, primarily by water vapor in the atmosphere. This design eliminates background signals from the surface of the earth, and also somewhat reduces the energy available from the missile plume. The water vapor content of the atmosphere at higher altitudes is not sufficient, however, to mask sunlight reflected from high clouds (typically 30,000 feet in the Arctic, and above 45,000 feet in the lower latitudes).

Whether the present MIDAS concept (IR search in the 2.65 - 2.8 micron band, looking down on missiles against an atmospheric background) can be made to operate successfully depends upon the radiant intensity of the actual missiles to be detected and the not yet determined character of cloud backgrounds.

The radiant intensity per unit solid angle in the MIDAS band of representative U.S. missiles is shown below.

Radiant Intensity (MW/steradian) in 2.65 - 2.8 Microns

Missile Type	Side-to-Tail Aspect	Frontal Aspect
ATLAS/TITAN Booster (LOX-RP1 Fuel)	3 - 6	.4 - .7
ATLAS/TITAN Sustainer (LOX-RP1 Fuel)	.075	.075
ATLAS/TITAN Booster (LOX-AMINE Fuel)	.5 - .7	.07 - .09
MINUTEMAN 1st Stage	.8 - 1.0	.08 - .01
POLARIS 1st Stage	.25 - .5	.025 - .05

The present MIDAS IR payloads (series 3 and 4) have been designed with good margins of sensitivity for targets with radiant intensity of .3 MW/steradian (out to a range of 4,000 miles) in the absence of cloud backgrounds. This sensitivity could be bettered by a factor of 10 (i.e. the proposed design for series 5) if found desirable. Thus, all the listed targets could be detected by MIDAS as presently conceived. Furthermore, there are no reasons to believe that Soviet ICBMs or large IRBMs would have lower radiant intensity (except, perhaps, if designed to circumvent MIDAS).

While equipment sensitivity does not seem to set a significant lower limit on the intensity of missile plumes that MIDAS can detect, background signals which lie in the 2.65 - 2.8 micron band do. These result from sunlit high clouds (other energy sources appear to be negligible in comparison).

As the MIDAS IR search cells scan, highlights in the illuminated clouds of extent comparable to a missile plume will appear indistinguishable from a missile of radiant intensity comparable to the highlight. If the system threshold were low enough, the highlight would cause a false target. Determination of the number of false targets we must anticipate has been a major (and far from completed) goal of MIDAS flights and the associated measurement programs.

Incomplete as these measurements are, data from balloons, U-2 flights, and Discoverer satellites give a more or less consistent picture which indicates that the false alarm problem will almost certainly be a severe one. The results of a series of U-2 flights have been interpreted in terms of MIDAS false target rate. Just how often conditions give rise to the indicated false target rates (or perhaps higher ones) is not known, but rates as shown below are believed to be not uncommon.

Threshold Set for Targets as small as:	Number of False Targets Per Scan
ATLAS/TITAN Booster (Side aspect, LOX-RP1)	1 - 10
MINUTEMAN 1st Stage (Side aspect)	1,000
ATLAS/TITAN Booster (Side aspect, LOX-AMINE)	1,000 - 2,000
POLARIS 1st Stage	2,000 - 4,000

Insufficient data is available for estimating the false target rate to be expected from a threshold setting low enough to accept the reduced radiance of missile upper stages or boosters viewed from the forward quadrant, but there is no reason to think that the false alarm rate will not increase rapidly when the threshold is lowered.

A few single scan false targets present no problem to MIDAS. Before the MIDAS data processor computes a MIDAS alarm, targets are tracked for about 6 scans (one minute) and continuity of track is required before a single missile is considered detected. Further, since MIDAS alarms only on mass raids (for example, 5 missiles seen in 5 minutes), an occasional accidental single missile detection would not be of consequence. Depending on the sophistication of the data processing and the excellence of the satellite attitude stabilization equipment, a few tens to a few hundreds of random targets per scan can be counted on to produce false single missile tracks no more often than daily, and raid false alarms once in many billion years.

A much higher false target rate (few hundreds to a few thousands per scan, if purely random, would present serious, but perhaps not insuperable, problems, although the minimum alarm raid size might have to be raised. The data processing and communications problems this would necessarily raise have not been deeply considered.

These estimates have been based on false targets which appear at random over the field of view, uncorrelated from scan to scan. It is quite certain that cloud background (essentially the only source of false targets in a properly operated MIDAS) does not generate targets at random.

Just a few cloud targets could be fatal to the MIDAS system if cloud shapes frequently were such that the highlights seemed to move over the earth as MIDAS moves, and the duration of highlight signals from a particular cloud were only a minute or two.

On the other hand, hundreds or perhaps thousands might be tolerated if they were apparently motionless with respect to the earth and persisted for many minutes, or if they were densely packed in a small part of the field of view. Analysis of the kind of data that only weeks or months of a fully successful MIDAS flight can provide is essential if intelligent estimates of false target tolerance are to be made.

Based on "best guesses" of the characteristics of cloud highlights, and paper inventions of clutter suppression techniques very roughly 1,000 false targets per scan would seem to be the maximum tolerable, but this could turn out to be in error by a factor of 10 in either direction.

While false alarms in the hundreds or thousands must be expected frequently from MIDAS as presently planned if targets of lower intensity than large ICBMs with LOX-RP1 fuels, new versions of MIDAS have been proposed which may have much greater immunity to the high cloud background. These are discussed below.

MIDAS Satellite Equipment Reliability DRAFT

The severity of the equipment reliability problem in the MIDAS system has been appreciated for several years. As a result, at least two independent reliability studies (by Aeronautical Radio, Inc., and by the Aerospace Corporation) have been undertaken to augment the day-to-day reliability engineering by the system contractor.

Two MIDAS configurations have been examined in detail, the Series IV-B (in which precise orbital position is maintained by ground-commanded cold gas jets) and the simpler series IV-X configuration in which no orbit adjustment (after initial injection) is provided. The Aerospace Corporation summary of the various Mean-Time-to-Failure estimates for the MIDAS satellite-borne equipment is shown in Table 1.

Table 1

MIDAS MTTF PREDICTIONS
(Data in Days on Orbit)

Configuration	Lockheed MSC	ARINC	A/S
Series IV-B	237	16	64
Series IV-X	870		162

The spread in these predictions reflects the great lack of precision in presently available techniques for predicting reliability.

These investigations have employed essentially the same method for predicting reliability. The investigations break down the MIDAS system into series elements* and estimate the system probability of failure to

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*The configuration also has parallel elements and branches which are accounted for properly in the calculations.

be the product of the probability of the individual elements. This process is carried down to the piece-part level, (i.e., transistors, gyros, connectors, etc.).

There is no apparent disagreement between the investigators on what the reliability model should be, but there is substantial disagreement on the mean-time-to-failure values appropriate to the piece-parts. Table 2 illustrates the failure rates used in the analyses.

Table 2
EXAMPLES OF ESTIMATED MIDAS PIECE-PART
FAILURES PER MILLION HOURS (Ref. 4)

Part	LMSC Estimate	ARINC Estimate	Aerospace Corporation Estimate
Gyros	12.5	91	50
Power Transistor	.1	40	4
Power Diode	.05	1.0	1.0
Signal Transistor	.02	6.0	.7
Fixed Resistor	.05	.5	.1

The spread in the estimates shown in Table 2 results from the fact that the piece-part reliability values used by LMSC approximate the test results that could be obtained by life testing individual components, while the ARINC and Aerospace values include a derating factor (based on experience) to allow for the inevitable imperfections in equipment engineering. The Lockheed life time predictions can be considered an upper bound on MIDAS satellite life which would apply if:

a. components (when individually tested) could actually reach the MTTF values LMSC quotes; and

b. the space environment does not materially reduce these values; and

c. MIDAS engineering in no way compromises the component inherent reliability.

Beneath this upper bound, the Aerospace values (or even the more pessimistic ARINC estimate) of 64 and 162 days for IVB and IVX respectively describe what well-designed military equipment of MIDAS' complexity operating in a surface environment can be expected to provide.

The reliability estimates must be subjected to further scrutiny when they are applied to equipment in space. The space environment differs materially from those in which experience and test results have been accumulated. In some respects it is probably less severe (e.g., very low mechanical forces, near constant temperature) and in others more severe.

The greatest present concern over the space environment has to do with the effects of the high particle flux of the Van Allen radiation belt on electronic components in the satellite. The presently planned MIDAS altitude (2,000 nautical miles) is known to be near the maximum of the Van Allen proton flux, but the proton flux and spectrum at this altitude are not yet well established.

The adverse effects of the Van Allen radiation will primarily be on semi-conductor components although some darkening of glasses and gumming of lubricants can be expected.

Solar cell performance deterioration to 75% of initial efficiency is expected after weeks or months, although this would be ameliorated by heavy fused silica shields (2 cm on each side of the panels). Whether further substantial deterioration can be expected (even for unshielded cells) is not known. Power diodes may suffer somewhat, but redundant design (for other reasons) may be adequate. Some sensitivity loss in lead sulphide detectors is known to occur, but does not appear to be of great significance.

These effects would be more severe if the radiation flux turned out to exceed presently estimated values. If this level is not exceeded, it still is to be expected that the cumulative effects of the damage anticipated will surely adversely affect life, although not necessarily significantly if sufficient care is taken.

The fact that the unbiased estimates (and all orbital experience so far) predict we will fall far short of one year mean life on orbit reflects not only the difficulty of the job but also the inadequacy of its execution to date. Three comments seem appropriate:

The system concept must be formulated with equipment reliability a major focus of attention. The 4X proposal seems to go in this direction, but there is no indication that very much more cannot be done towards simplification of the satellite.

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In the past flight schedules have paced the program, rather than achievement of flyable equipment. This trend should be reversed. Life testing of completed equipments destined for orbital use should be mandatory.

The MIDAS satellite presents one of the very few most difficult system reliability problems ever faced by the United States, and none of these is yet solved. It is clear that the organization and management of the program has not been appropriate to the magnitude of the problem.

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Other Technical Problems

While extraction of the signal in the presence of background, and equipment reliability are clearly controlling technical problems of MIDAS, there exist two other technical areas worthy of mention.

Attitude stabilization with very low rates of drift will be required if even a small degree of immunity to cloud background is to be achieved. As an example, a rotation rate as low as .01 degrees per second would give a cloud on the horizon apparent motion comparable to an ICBM and would break up the tracks of actual ICBMs to a degree that would jeopardize identification by track continuity. The present design target for the 4X concept is for rates less than .001 degrees per second. While no fundamental problems are foreseen in achieving these low rates, substantial development (including perhaps a new large precision gyro for space use) are foreseen.

The ground environment, including communications, displays, and computation will also be a controlling factor in determining the degree to which cloud background can be overcome. Present plans call for little capability in this area, equivalent to a maximum false target rate of 200 per scan. Technological limits do not seem to be in question, but system design and optimization in light of the growing knowledge of the targets and background is clearly necessary.

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VII. SUGGESTED RESEARCH PROGRAM:

The single greatest uncertain physical parameter of MIDAS is the statistics of the background clutter. This statement does not imply that all targets parameters are firmly established even for U. S. missiles.

For the present design concept, namely an earth looking scanner in the 2.7 micron band, the sunlit cloud creates the background clutter. For any new concept the background clutter will evidently depend on the selected spectral region and method of discrimination. Let us first consider the IR research program in support of the present MIDAS concept.

1. Partially modify present Series III payloads, to meet the specific requirements for background data.
2. Initiate a program which uses simple, reliable orbital vehicles specifically designed to collect cloud background statistics.
3. A vigorous effort, with sufficient priority, in target measurements is needed (a) to clarify several critical parameters for Atlas type fuel systems, (b) establish experimental values for LOX-amine engines, and (c) obtain reliable experimental data for solid propellant engines. This can be accomplished by additional rocket and pod experiments and the instrumenting of several

additional U-2 aircraft with proper instrumentation.

4. Added emphasis should be given to determine the effectiveness of flame quenching additives and the propulsion problems related to their use.

5. A comprehensive well funded program of IR component reliability, particularly in a space environment, is sorely needed.

To extend the MIDAS concept possibly to other spectral regions or radically different discrimination techniques then the background clutter will depend upon the selected spectral or technique employed. The research program needed for this type of effort and outlined below must be meshed with existing projects.

1. An enlarged effort to document such backgrounds as auroral, air-glow and stellar in various spectral regions. The measurements should stress completeness of spectral and spatial coverage and fluctuations.

2. Accelerate the technology of IR detectors in other spectral regions so that the state-of-the-art becomes comparable to lead sulfide.

3. To optimize the capability of the detectors in (2), simple reliable, long-life cell cooling techniques must be investigated.

4. Initiate a measurements program, preferably piggy-back, to determine target emissions from 500 microns to 5000 microns.

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VIII. CONCLUSIONS AND RECOMMENDATIONS.

Once one has satisfied one's self that a successful MIDAS design would meet important military and political needs (see section "The Uses of MIDAS"), questions arise as to how the existing MIDAS program is progressing toward their fulfillment, and what changes, if any, are needed. One can examine a spectrum of possibilities ranging from an immediate deployment decision to complete cancellation of the R&D program. In order of decreasing emphasis, various alternatives may be listed.

I. Go operational with present design as rapidly as possible.

II. Continue with present program.

III. Cancel present design and redesign to a simplified MIDAS (Series 4X) as rapidly as possible with the aim of going operational at the earliest date. Increase supporting R&D.

IV. Drop the idea of going operational at any early date and radically alter program to an R&D IR satellite technology program.

V. Cancel MIDAS.

The controlling factor as to which of these alternatives is chosen is dependent on a technical estimate as to whether or not MIDAS can achieve its design goals. Here the conclusions seem to be:

1. That the existing design (Series 4) is unsatisfactory, due to reliability considerations alone.

2. That a much more reliable MIDAS design can probably be achieved.
3. That such a redesigned MIDAS has an excellent chance of being able to detect large liquid-fueled ICBMs, at least of the high radiance type.

Since MIDAS is needed, and since it will probably work against at least one important class of enemy ICBMs, we reject V. An additional and important reason for rejecting V is the importance of maintaining an option in satellite IR technology.

Since the existing design (Series 4) is unsatisfactory, we reject I and II. We are then left with III and IV, or some combination thereof.

The argument against III is that we really do not have enough data on reliability and IR background to justify an effort geared to attaining the earliest possible operational date. There is doubt that Series 4X will be adequate.

The argument against IV is that we are greatly lessening the chances of getting an operational MIDAS before, say, 1968-70.

This suggests the following procedure: that the design work (but not fabrication) of the simplified MIDAS go immediately forward. This will permit two important things which alternative III would not possess. First, it would permit the results of the Series 3 flights, which will be taking place during 1962, to influence the design. Second, it would permit consideration of other changes to the 4X design in the direction of increased reliability and effectiveness. For example, effective calibration in flight of the IR cells might be worked out. At such time as the information warrants, fabrication of prototype vehicles may be authorized.

If all goes well, one might, with this program, get an effective operational system in 1966.

At the same time, recognizing that the above design may fail, and that even if it does not, it will probably <u>not</u> be effective against smaller missiles, there should be an active study and development effort on advanced payloads, other frequency bands, changes in geometry, etc., which may be required to advance MIDAS capability substantially. This in turn could lead to an advanced MIDAS which might become operational two or three years later than the initial version (assuming the initial version is successful).

It may be desirable to handle the management of the advanced MIDAS program somewhat differently than that used to handle the initial version, to insure that adequate attention is given to basic developmental problems.

Finally, it is of great importance that a supporting basic research and measurements program be carried on in parallel with the above efforts. Examples of the type work envisioned would be radiation measurements and studies of cloud statistics. It is strongly felt that management of this effort should be divorced from the management concerned with developing MIDAS hardware, in order to insure that proper, intelligent and comprehensive research is accomplished. This conclusion is buttressed by the experience in MIDAS of the last several years, in which fundamental measurements have been neglected or started too late to influence system design.

Recognizing that we cannot now predict the performance of an operational MIDAS, no operational date should be specified until enough information is at hand to be able to predict capabilities, schedules and costs with confidence.