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HEADQUARTERS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
ANDREWS AIR FORCE BASE
WASHINGTON 25, D. C.

REPLY TO
ATTN OF: MSF

SUBJECT: Tagboard ~~(S)~~

Draft

TO: SCG (General Schriever)

1. The attached study analyzes the Tagboard system from the standpoint of operational effectiveness, risks involved in its use, and costs. The study recommends termination of the Tagboard program.

BAS -
CIA HAS
TRANSFERRED
PROG. TO
AIR FORCE.
(NRO)

2. Because AFSC and the Air Force have no accepted responsibility for the Tagboard program, the conduct of this study may be considered by some people to constitute unwarranted interference with another organization's programs. Since AFSC actions in the covert reconnaissance area are dependent on personnel clearances and the willingness of others to discuss problems with us, we should be careful in the handling of this study so as to not get the wrong people mad at us at the wrong time.

3. It is recommended that the material in this study be discussed only at the Secretarial level or higher (Mr. Zuckert, Mr. Gilpatric, Dr. Wiesner). It has been alleged that Dr. Fubini was the original supporter of Tagboard and it is, therefore, possible that an approach at the Fubini level or below might be considered a personal affront and suffer in proper staffing or handling. It is preferred that the study be considered an in-house document and only be used as the basis for discussions. If we can generate concern at the higher levels and have questions passed down to the staffs on reliability, costs, etc., it is quite possible that the study recommendation would be achieved. This approach may be enhanced by the present shortage of funds for proper R-12 support. If this indirect approach doesn't work we could, after consideration of the possible consequences, try a more direct approach.

BAS - THIS IS A WORKING
PAPER - SEE MY
NOTES.

WORKING PAPERS

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FORGING MILITARY SPACEPOWER

BYE 11451-63

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TAGBOARD STUDY

18 October 1963

EXCLUDED FROM AUTOMATIC
REGRADING; DOD DIR 5200.10
DOES NOT APPLY

Prepared by:

Director of Advanced Methodology
(MSFAL)
Hq Air Force Systems Command

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I. PROBLEM: Should the U S Support the Tagboard (MD-21) Program?

II. CRITERIA:

GENERAL WAR

A. To warrant support, the Tagboard system should possess a reconnaissance capability not available through other systems or its cost/effectiveness should be better than competing systems.

B. Aside from costs and capability, this system must have characteristics such that its utilization should be approved by the President. That is, that the risks inherent in its use are sufficiently low and are outweighed by the value of the reconnaissance data to be obtained.

III. ASSUMPTIONS:

A. The only important application of the Tagboard system (MD-21) is the covert peacetime reconnaissance of the Soviet Union. —?

IV. FACTUAL DATA

A. Tab A provides information on the nature of the Tagboard program including performance, cost, and schedules and a brief technical evaluation/discussion of some of the problems.

B. Tab B provides a summary of USAF experience on aerodynamic missile reliability.

C. Tab C is an analysis of the relative survivability of the A-12 and Tagboard systems in the current peacetime Soviet environment.

D. Tab D gives a comparison of the reconnaissance sensor performance for the Tagboard, A-12, and R-12 systems.

E. Tab E is an analysis of Air Force experience in the recovery of capsules ejected from satellites.

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V. DISCUSSION:

A. Effectiveness:

For this study, the reliability, survivability, reconnaissance sensor performance and probability of data recovery will be reviewed as indicators of effectiveness. Tabs B, C, D, and E provide information on these factors. The following summary can be made of that data:

1. Reliability. USAF experience on the GAM-72, GAM-77, and Bomarc B indicates that the in-flight reliability of aerodynamic missiles of similar or less complexity compared to the D-21 range from 56% to 78% according to the weighting given to ? partial success. Since many of the test flights had limited objectives, it is probable that many of the partial successes should be charged as failures for an operational type study. This would result in an in-flight reliability experience much less than 78%. It is interesting to note that none of the missiles examined (including the unsophisticated Q-2C) achieved much over 80% in-flight reliability during their test programs. Although there are differences between the D-21 and missiles reviewed, it would be considered optimistic to expect the D-21 to achieve an in-flight reliability of 80% without a much longer, more extensive and expensive development program than is now planned.

2. Survivability. It is expected that the radar cross section of [redacted] those values. Using conservative estimates of Soviet SAM capabilities, the following conclusions on relative survivability of the A-12 and D-21 can be made (See Tab C):

MAIN POINTS FOR D-12

   a. Neither the A-12 or D-21 can expect to penetrate without detection. ?

   b. Survivability of either vehicle is dependent on the need for near perfect performance of the SAM battery tracking radars. ?

   c. Against the Fruit Set "B" tracking radar with perfect radar and SAM missile performance, the D-21 would gain immunity with a track offset of 15 to 20 nm while the A-12 would require offsets of 20 to 30 nm. Considering differences in navigation capability, the D-21 would have to be programmed for nearly as much track off-set as the A-12 to achieve equal immunity from a particular SAM battery.

d. There is no apparent basis for crediting the D-21 with significantly better survivability than the A-12. ?

RELIABILITY

3. Reconnaissance Sensor Performance. The photographic sensors of the D-21 and A-12 vehicles are expected to give equivalent performance. It is interesting to note that the R-12, a derivation of the A-12, provides improved photographic resolution and accommodates a large assortment of active and passive sensors which could probably be adapted to the A-12 if future requirements dictate.

4. Data Recovery. The recovery of the data from the D-21 involves air pick-up or surface recovery of a capsule similar to but much heavier than that used on the Discoverer program. The last two years' experience on the Discoverer capsule recovery program (involving 31 attempts) indicates at most an 84% probability of recovery of the D-21 data unless great improvement is made in recovery techniques and design reliability. The A-12 flys home with its data or, in an emergency, would recover at a foreign base. The probability of recovering the A-12 reconnaissance data after an otherwise successful mission is very high.

AT ONE LOCATION

5. Effectiveness Summary. The much higher in-flight reliability of the A-12 together with its better method of data recovery will make it much more effective than the Tagboard (MD-21) system. Both systems are believed to have substantially equivalent ability to survive probable enemy action and they have equivalent reconnaissance sensor capabilities.

B. Presidential approval to conduct covert overflight reconnaissance.

1. General. Peripheral and overflight reconnaissance must be specifically approved by the President. It is presumed that the President will approve such operations when, at the time in question, the need for specific reconnaissance warrants the

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CONTINUOUSLY -
TOO MUCH
STANDDOWN
TIME
COST EFFECT.

risks involved (in his opinion). Everyone will agree with the general need for intelligence data but the urgency that will be attached to it varies from time to time and with the personal views of the President. On the other hand, except as political/diplomatic events (i.e., imminent Summit Conferences, etc.) affect risks for a short period, the risks seem amenable to fairly long term analysis. With either the A-12 or the Tagboard (D-21) system, the risks primarily involve whether the vehicles go down in Soviet territory and what, if anything, the Soviets can do with the resulting evidence to embarrass us. The A-12 and D-21 will be compared on that basis.

2. The occurrences which could result in either of the vehicles going down in enemy territory are in-flight failures, which may be measured by reliability, or by hostile enemy action which may be measured in terms of survivability. We have examined the reliability of drones/missiles in Tab B and find that experience indicates a probable in-flight reliability of less than 80% for the D-21 (it could be much less). This compares unfavorably with the in-flight reliability of manned aircraft. From the survivability analysis (Tab C), it was concluded that the survivability of the D-21 would not be significantly different from that of the A-12. It appears then that the use of the D-21 would be much more risky than use of the A-12 from the standpoint of leaving incriminating evidence within the Soviet Union.

3. If either the A-12 or Tagboard (D-21) go down in the Soviet Union for any reason, it is difficult to estimate the final condition of the wreckage. Both systems will employ destruct packages to destroy the data, cameras, and vehicles. There is no reason to expect different results if destruction is initiated. The fact that the A-12 has a pilot probably insures a higher reliability of destruction being initiated because he has a manual destruct capability. It seems that with the A-12, there is less chance that the enemy could prove the sensor capability. Of course, the pilot of the A-12 is a problem. If the pilot lives, he can be tried in court before the world - for what its worth. However, except for pure propaganda aimed at the naive, it is doubted that a living pilot is any better evidence than sophisticated hardware obviously made in America.

4. In summary, it appears that for an equivalent number of missions, more D-21's than A-12's would go down in the Soviet Union. This probably makes the true risks of employing the D-21 greater than using the A-12. OK

C. Costs:

1. The present MD-21 program calls for fabrication and test of 19 D-21 drones and modification of two A-12's to the M-21 configuration at a cost of $65 million. From Tab B, we would expect the cost of development and test to achieve 80% in-flight reliability for the D-21 to be more nearly $150+ million and involve 50 to 60 test flights.

LOW COST EST.

2. For operations, it is expected that $150 million would be required to acquire an operational fleet of 5 carriers and 30 drones. Costs of recovery operations and M&O costs have not been estimated.

3. It appears then to have an operational capability of any significance, the Tagboard system would require expenditure of over $300 million exclusive of M&O and recovery costs. For the A-12 program, acquisition costs will be about $500 million but much of this has been already invested. Various comparisons of the relative costs per sortie indicate the MD-21 system to be 4 to 30 times as costly as the A-12. In any case, it is estimated to be more costly than the A-12 on a sortie basis. VS SATELLITES?

NO SPP APPROACH

VI. CONCLUSIONS:

A. The A-12 program is estimated to have a much greater operational effectiveness in securing desired specific reconnaissance data than can be achieved by the Tagboard (MD-21) system.

B. There are equal or greater risks involved in conducting overflights with the D-21 drone as compared with the A-12.

C. Costs of acquisition and operations of the MD-21 system will be several times that of the A-12 on a sortie basis. Costs will also be much greater than now planned.

D. The Tagboard program is aimed at achievement of a capability inherent and available earlier in the A-12.

VII. RECOMMENDATION:

That the Tagboard program be terminated (and that planned funds be allocated to the R-12 program).

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SAME AS OTHER D-21 PAPER. ✓

EVALUATION OF THE MD-21 DRONE RECONNAISSANCE SYSTEM

Description

General

The system under consideration is a composite of the A-12 airframe plus a small, ramjet powered reconnaissance drone. Design of both airframe features a high fineness ratio fuselage chine combination, thin, low aspect ratio wings and vertical tail surfaces, and high strength titanium and plastic structure.

Carrier

The carrier aircraft is basically the same as the A-12. Modifications to this basic design to enable it to function as a launching platform include the following:

1. A launching subsystem will be attached to the upper surface of the aft fuselage. As originally conceived, the launcher consisted of a pair of one inch rails attached by a release mechanism to two fuselage stations on the missile. These rails are supported by a four-bar linkage hinged to a pair of rails attached to two fuselage stations on the carrier airframe. Unequal lengths of the actuating arms of the four-bar linkage allow the drone to be positioned for minimum drag during captive flight, and to be positioned for desired angle of attack when erected and ready for launch. Subsequent studies indicated that the drone could be successfully launched from the cruise position, and the elevating mechanism discarded. Wing tunnel tests to confirm the calculations are now in progress.

2. The fuel system will be modified to interconnect the missile and carrier fuel systems. This will permit the use of the missile fuel in the carrier during return to base in the event of an aborted launch, and will also permit replacement of hot fuel in the missile with cooler fuel after any in-flight refueling. Provisions will also be made for pressurizing the missile fuel tanks from the carrier nitrogen pressurization system.

3. An air line will be provided to supply air to the secondary power drive turbine while the drone is in captive flight.

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TAB A

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4. The equipment bay area of the A-12 will be converted to a second cockpit for the drone launch control officer.

Drone

The reconnaissance drone is a composite titanium-plastic structure which repeats the distinctive fuselage-chine combination of the A-12. Length is approximately 42 feet, span of the delta wing is approximately 20 feet, and loaded weight is approximately 11,000 pounds, of which about half is fuel weight. Structural material is titanium except for wing edges, inlet spike, and the vertical fin~~s~~ which are made of a structural plastic. The modified RJ-43 engine is installed in the aft fuselage and the duct runs the full length of the fuselage from a fixed geometry spike in the nose. Design load factor has been increased from 2.5 in the original design to 5.0 to permit a high speed terminal dive. Space for installation of payload, navigation system, secondary power system, cooling system, and other ancillary equipment is provided in the fuselage chines and in the fuselage beneath the engine inlet duct.

Technical Evaluation

Air Vehicle

Modifications required to convert the A-12 to a missile carrier are not trivial, but they require detail engineering rather than innovation. Redesign of structure in the aft fuselage to distribute captive and launch loads will be required, and complete redesign of wiring harnesses and fluid and gas line routings will be required. Modification to provide a second cockpit will make use of AF-12 design experience.

Drone Airframe

The significant problem in the missile airframe design lies in realizing a relatively inexpensive structure with the desired low radar cross section and adequate strength. [redacted] The contractor states that solutions to the problem are in hand, based principally on proper shaping of joints, providing no major airframe design changes are required. Weight estimate has increased about 150 pounds since the design was started but offsetting gains in the propulsion system have preserved performance capability. The design contemplates use of insulating material to reduce transfer of heat to the fuel. The present plan is to spray coat the external surfaces over fuel tank areas with approximately 0.4 inches of insulation. The insulating material is a rubber-like compound and test applications to test panels are proving successful.

Propulsion

The basic concept of using a ramjet for the missile propulsion system is excellent. Indeed, an application that requires operation over a limited range of high airspeeds is ideal for a ramjet. The particular engine proposed is a well-developed unit, of demonstrated reliability, and has been flown experimentally at speeds in excess of M 4.0 in the X-7. The installation proposed by the contractor includes a simple external compression, fixed geometry inlet spike, and a tail pipe shortened by approximately 30 inches from current RJ-43 design. A few preliminary tests have shown no significant change in engine performance with the shortened tail pipe. A recent experiment, increasing the divergent portion of the exhaust nozzle by 7 inches, has shown a 4% increase of thrust and will be included in the design. Since the basic RJ-43 engine and installation have been significantly changed, current testing will need to be continued and expanded to include comprehensive tests of the whole propulsion system including inlet, burner, and nozzle. This testing should be comprehensive enough to establish performance and repeatability in the operating envelope. Some "tailoring" will almost surely be necessary to solve thrust, fuel consumption, drag, combustion stability, and ignition problems.

Wind tunnel testing of the inlet has already shown peak ram recovery of 83% versus the 74% assumed in performance estimates. Wind tunnel drag measurements, approximately 7% higher than the design estimate in June, are now reduced essentially to the design estimate level.

The other significant problem is the development of an ignition method which is in effect 100% reliable. Flow conditions for ignition are critical, and considerable effort on an ignition system is expected before an operational system is established. The ignition system must also provide blowout protection during and immediately following launch when flow conditions are other than normal. The contractor has concluded that the best solution to this problem lies in the application of a pyrophoric ignition system using the same starting agent (Triethyl Borane) employed in the J-58 engines of the launch aircraft. Present design allows sufficient quantity of the starting agent to accomplish eight starts. Because of the critical conditions encountered at launch and the potential for a catastrophic failure, the earlier evaluation group recommended consideration of continuous flow of the triethyl borane during the launch sequence.

Navigation and Guidance

The navigation and guidance problems for the drone reconnaissance system are essentially the same as those presented by an air to surface missile. Major elements of the problem are establishment of initial conditions for the drone at launch, and accuracy of drone guidance during its independent flight. The range of coverage provided by the camera, however, leads to a reduction of accuracy required, as compared to an air to surface missile application.

The present design has a stellar-monitored inertial navigator in the carrier, and an unaided inertial system in the drone. The operational concept envisages ground alignment of both systems prior to take off, and independent navigation by both systems to the launch point. Prior to launch, the Launch Control Officer will reset the position indication of the drone guidance system to coincide with position indicated by the stellar inertial system of the carrier. The presumption is, of course, that the carrier system is more likely to be correct, and since it has the stellar adjunct, this presumption is reasonable. Accuracy specification for the stellar-monitored system in the carrier is a bounded error of not greater than 2.8 nautical miles. Navigational accuracy of the unaided inertial system of the drone will degrade with time but should be no worse than 2 to 3 nautical miles per hour for launch within two or three hours after take off. At the end of a 3000 mile reconnaissance flight, therefore, navigation CEP of 5 nautical miles appears to be a reasonable estimate.

The equipment proposed for the navigation and guidance functions is a further growth of the MH-330 equipment now being supplied for the A-12. Only the basic gimbal structure is preserved without change. For the carrier, a Kollsman star tracker is mounted in conjunction with the gimbal system, and the two elements are coupled by optical links. The drone platform is essentially identical to the MH-330. Computers in the drone and in the carrier will be identical and will be based on the PICO computer developed by Honeywell as a company project. Each computer has more capacity than is required solely for navigation or guidance computation. Excess capacity in the carrier will be used for the sychronizing functions between the two as well as for other required vehicle computation functions. The excess capacity of the drone computer will be used for pre-launch go-no-go checks. By programming the computer to direct the checkout, the number of umbilical connections to the parent aircraft can be significantly reduced.

Accuracy numbers quoted appear well within current state of the art, and while this accuracy level is unattractive in weapon delivery, it is adequate for the reconnaissance mission.

Camera

The drone payload is a single camera of 28 inch focal length. The film magazine capacity is 4500 feet of 9 1/2 inch thin base film which is sufficient to provide continuous coverage for 3020 nautical miles of drone flight. Lateral coverage is 14 nautical miles either side of flight path. Five fixed depression angles are provided, one vertical and 19° and 36° above the vertical on either side. Frame overlap is 60% up to ± 30° from vertical and 40% to ± 45° from vertical. Camera is stabilized in pitch and roll. Camera specification calls for weight of 385 pounds versus an allowance of 500 pounds used in original performance estimates, so that an adequate margin for weight growth is available.

Launch and Recovery

The launch operation presents some severe analysis and design problems. Complexities arise from the following:

1. The drone and carrier configurations provide only 14 inch clearance between the D-21 wing tips and the M-21 vertical stabilizers. Yaw and roll control of the drone at launch must, therefore, be very precisely controlled.

2. The flow field through which the drone must fly is very complex and includes a pattern of shock waves generated by the carrier nose, engines, and wings.

3. Upon release of the drone, air loads, as well as weight loads on the carrier may change abruptly, posing control problems for the carrier vehicle.

4. The inlet for the drone engine is a single point design which makes it possible to provide good performance at design point, but also causes very rapid degradation if conditions vary from the nominal. Effects of penetrating the nose and engine shock waves on engine performance are unknown at present.

As presently planned, prelaunch operation will include comprehensive checks of the drone guidance system, flight control system, secondary power system, and fuel system. Streamlining cones on the drone duct will be removed, the aft closure by firing explosive bolts and the forward enclosure by a retractor. The engine will be started and its performance monitored by comparison of combustor pressure against a pre-set standard. Since safe separation is critically dependent upon the drone autopilot performance, about 50 distinct go-no-go functions will be tested through the guidance computer. When all performance checks are complete, a panel indicator will show ready to launch, and the drone will be released.

Present tunnel data indicate that, upon release, air loads will cause drone and carrier to separate and will also cause a nose up pitching moments a short time later, perhaps a tenth of a second, the pitching moment will reverse, and another tenth later, as the drone penetrates the nose shock, it will reverse again. It is now planned that the flight control system will operate on a constant normal acceleration signal for 15 seconds after launch and will then switch to Mach hold.

There is nothing to indicate that safe separation of the composite aircraft cannot be accomplished. On the other hand, it is apparent that a considerable effort in analysis, wind tunnel, and flight test will be necessary to assure safe and effective drone launch. [Jettison, in the event of a drone failure has not yet been analyzed.]

Recovery of reconnaissance data will be accomplished by ejecting a package containing the camera, the navigation system, electronic components of the flight control system, beacon and command receiver. The total package weight is currently estimated at 880 pounds. Recovery operations will start with engine shut down at a programmed position. The drone will descend at constant ram pressure to approximately 40,000 feet, and will have a velocity of M 1.0 to M 1.4 at that altitude. The recovery package will be ejected at that point, and will be further slowed by deployment of a parachute. Primary recovery method will be the air pick up technique used for recovery of Discoverer payloads. In the event the pick up is not successful, surface recovery is possible, since the package is designed to float. Although some detail design has not been completed, e.g., ejection method, parachute size, the concept has been demonstrated, and payload recovery appears to be a completely feasible operation. ②

RECOVERY FLEET - i.e. A.C. TYPES

Other

Secondary power for the missile will be provided by a ram air powered turbine driving an alternator and hydraulic pump. During the descent, prior to payload ejection, power will be provided by a battery-inverter system.

A command receiver will be included to permit command control of fuel cut off, beacon operation, package ejection, and drone destruction. A self-contained destruct system will also be included. The logic for arming and tripping the destructors are under study. Development problems in these areas remain to be solved, but there appear to be none which influence feasibility of the concept.

Performance

Drone

The D-21 has been designed for a nominal range of 3000 nautical miles. Variations from original design estimates to the present have been both favorable and unfavorable, so that the nominal 3000 mile range remains a good estimate. Launch altitude is 75,000 feet, and since cruise operation is at constant Mach number, the drone will climb continuously, and will reach 95,000 feet at the end of a 3000 mile leg. Two mission profiles are shown in the charts following, one for operation from a staging base, without in-flight refueling, and one with two refuelings. The map chart indicates potential flight paths with this range capability.

Camera

The camera specification calls out system resolution of 120 lines per millimeter or ground resolution of about 1.25 feet from nominal 85,000 foot operational altitude. The opinion of a consultant from the Reconnaissance Division, Air Force Avionics Laboratory, based on evaluation of the details of camera design, is that 70 lines per millimeter, or about 2 foot ground resolution against medium contrast targets is a very reasonable estimate of the camera potential.

? cost 3-5 vs 1.25-2

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Costs and Schedule

Both cost and schedule data are very inexact at present. Information presented below is best available at present, but may change radically.

Schedule

The present program calls for fabrication and test of 19 drones, and modification of two A-12 airplanes to the M-21 configuration. The first drone is now scheduled for completion in April 1964, and the first carrier will be delivered in June 1964. The final drone will be delivered approximately one year after the initial delivery. Without the benefit of a detailed flight test plan, the project engineer estimated that 12 to 18 months of flight test would be required prior to any operational commitment. These estimates argue an operational capability early in 1966. This is an extremely optimistic estimate, and probably represents a possibility if no unanticipated development problems arise. For comparison, the original GAM-77 schedule allowed four years from initiation to operational capability, and was considered so optimistic as to approach the ridiculous. ~~In the event~~ Direction was given to accelerate the program, but the development flight testing was nevertheless completed approximately a year later than planned on the original schedule. The parallel is not exact, but is an indication that the schedule is optimistic. An estimate of operational capability in mid-1966 is reasonable providing no major development problems arise.

Cost

This estimate is believed to be so low as to be unrealistic.

Original estimates for the present drone development program have grown to present estimate of $65 million. A planning estimate of $52 million for an additional 30 operational drones has been made. Given an operational program, additional mother airplanes will probably be required, at an acquisition cost of $20 million per aircraft.

All Hi Cost Items —

Cost of acquisition or modification of recovery aircraft~~, in the event current inventory is insufficient~~, has not been estimated nor has maintenance and operations costs.

Cost of acquisition of recovery aircraft and ships for sea search and pick up will greatly increase program costs

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Summary

Progress in development of the DM-21 system is on schedule, and the performance estimates still appear feasible. If no major development problems arise, a drone reconnaissance system could be in operation by the middle of 1966 which can provide photographs of about 2 foot resolution over the full length of a 3000 mile flight. Camera field and expected guidance accuracy are compatible, so that a high probability of actually covering desired targets can be expected.

Development cost estimate is $65 million. An additional $150 million would be required to acquire an operational fleet of five carriers and 30 drones. Costs of recovery aircraft and M&O costs have not been estimated.

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MISSILE RELIABILITY

1. Data from earlier missile development programs do not establish limits for cost, reliability, or development time, but they do provide a background of experience which can be used as a basis for evaluating perfections of current developments.

2. The GAM-72 is a small missile designed for carriage by B-52's. The payload is electronic equipment which causes the GAM-72 to present a radar target similar to that of the B-52, and hence, to act as a decoy for enemy defenses. Propulsion is provided by a small turbojet engine.

a. The GAM-72 development program was started in 1957 with first launch in 1958. Category III testing was completed in 1961, and a follow-on test program of 8 flights was accomplished in 1962. Development program cost was $116.4 million.

b. During Category I, II, and III testing, the pre-launch and launch reliability of the missile was 63%. Figures to demonstrate a trend are not available. Flight reliability is shown in the table below:

MISSION DIFFERENCE—

No RECOVERY

Flight Experience

GAM-72

	Success	Partial Success	Failure	Total
Category I	18	4	7	29 76
Category II	12	2	4	18 78
Category III	2	2	2	6 67
Follow-on	7	0	1	8 88
Total	39	8	14	61

c. Definition of a "partial success" varies with the stage of testing but giving credit for partial successes, the flight reliability is 77% for the entire program. Probably a more realistic estimate of operational expectation can be derived from the Category III and follow-on test results. Again crediting partial success as adequate, the flight reliability is 78%.

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TAB B

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3. The IM-99B Bomarc is a ground launched, unmanned interceptor comparable in size to the D-21. Propulsion is provided by two Marquardt ram-jet engines. A rocket engine provides initial boost to drive the missile to ramjet operating velocity. The Bomarc B development program was started in 1957 and Category III testing was essentially completed in 1963. Total RDT&E cost was $322.4 million.

a. Although a total of about 75 flights were accomplished, readily available data are concentrated in 45 Category I, II, and III flights conducted in a two year period starting March 1961. Failures during this period were as follows:

Target Seeker	8
Electrical System	3
Flight Control	5
Miscellaneous	3
Total	19

These figures indicate a rather low 58% reliability. However, target seeker failures were not determined unless the missile actually reached the intercept area, so the probability that the missile will reach the target area is 78%. It is significant also that the ramjet engines have given completely failure-free operation. Since this engine is the same unit proposed for the D-21, demonstrated propulsion reliability is heartening.

b. The Bomarc project office has also gathered statistical data concerning pre-flight reliability of the missile and its support equipment. For the missile, pre-flight reliability is defined as the probability that a missile selected for firing will successfully pass through countdown and launch sequence. Category I, II, and III experience has shown this reliability to be 90%. The support reliability is defined as the probability that a weapon selected from ready storage can be prepared, counted down, and launched in a 60 minute period, and so far as supporting equipment is concerned, the demonstrated reliability is 100%.

4. The GAM-77, Hound Dog, is a cruise missile, designed for external carriage by B-52's. Of all the missiles previously developed by the Air Force, it is most similar to the D-21 in guidance and control equipment. Guidance is provided by an inertial system which is given pre-launch conditions from the parent airplane navigation system and a pylon mounted star tracker. Development of the missile started in 1957, and the R&D program was completed in 1962 at a cost of $194.4 million.

a. Reliability objective of the program was a 75% probability that an installed missile will survive an 8 hour captive flight, pass pre-launch and alignment checks, launch and fly 1/2 hour to the target area with less than 2 nm error. Available test results are as follows:

Hound Dog

Flight Reliability

	Success	Partial Success	Failure	Total
GAM-77 Cat I, II	15	11	6	32
GAM-77 Cat III	4	7	5	16
GAM-77A Cat I, II	8	2	1	11
Total	27	20	12	59

Again giving credit for partial success, the in-flight reliability for the total test program is approximately 80%. For missiles most nearly representative of operational configuration, the Category III GAM-77 and the GAM-77A, the reliability figure is 78%. Data to determine the probability of successful checkout at the end of some period of captive flight are not available.

5. At the other end of the complexity spectrum among Air Force unmanned aerodynamic vehicles is the Q-2C target drone. Development of this target was started in 1957 and the drone became operational in 1961. Development cost was approximately $15 million. Category III testing included 25 flights. Two drones were lost, and an additional four malfunctioned but were successfully recovered. Reliability requirements are stated in two ways. First, the probability of locating a drone in position and altitude for a hot run must be 90%, based on having two drones prepared for launch so that the second can immediately be launched should the first abort. Second, an average life of five flights per drone is required before operational loss occurs due to material or component failure. Both reliability requirements are being met. The first requires single target reliability of about 68%. The second requires reliability per flight of about 87% but allows for repair between flights.

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6. Despite the dissimilarity of mission, performance, and characteristics of the systems, there is a surprising consistency of flight reliability demonstrated of about 80%. This is perhaps the level at which current state-of-the-art reaches ~~to~~ the "knee" of a cost versus reliability curve. That is, higher reliability is certainly possible, but only by the expenditure of much larger amounts devoted solely to reliability. Development costs in themselves show no such pattern with RDT&E varying from $116 to $322 million (neglecting Q-2C). Difference between the GAM-72 and the GAM-77 can easily be explained by the greater complexity and higher performance requirements of the latter. Higher cost of the Bomarc may lie in the more elaborate ground launch equipment requirements. It appears, however, that expenditure of the order of $150 to $200 million is a minimum to bring a sophisticated unmanned system to operational status.

7. Investigation of any one missile program is likely to be misleading, because of limited sample size, particular mission, or particular design problems. Combining results may provide a more meaningful standard.

Missile Test Experience VS OPERATIONAL

	Success	Partial Success	Failure	Total
GAM-72	39	8	14	61
GAM-77	27	20	12	59
BOMARC B	26	8	11	45
Total	92	36	37	165

No REC.

Giving credit for partial success, the over-all flight reliability is 78%, while counting only successful flights, the flight reliability is 56%. The inclusion of partial successes in the computation may also be misleading because of lack of definition of what constitutes a partially successful test flight. Definitions such as "50% of the test objectives accomplished" are frequently used and are completely valid for an R&D test program. Categorizing such an event as successful in an operational context, however, is completely unreasonable. Based on cumulative experience, we may predict that in-flight reliability of the D-21 can probably be no worse than 50% given reasonable attention to good design, and a test program adequate to uncover problem areas. We can also predict that expenditures of $150 to $200 million, and a flight test encompassing 50 to 60 flights covering a 4 plus year development span would be required to achieve in-flight reliability of 75 to 80 percent. To achieve reliability beyond that level or to predict the cost in dollars or development time requires an extrapolation into an unknown area. We can be sure only that the cost relationship to reliability is not linear, but that we could expect larger dollar amounts to accompany each incremental increase of reliability.

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DETECTION AND SURVIVAL

1. Effectiveness of any system designed for covert aerial reconnaissance is dependent upon the ability of the reconnaissance vehicle to operate over its targets with immunity from the most effective defensive measures available to the adversary. The potential for national embarrassment inherent in the concept of covert reconnaissance demands that major effort be devoted to design for survival.

2. Air defense capability today, and for the foreseeable future, is based upon radar detection of potential targets and destruction of targets by guided missiles. Although infrared terminal guidance is certainly a feasible technique for a surface to air missile, some mechanization of radar guidance would still be required for mid-course, for target position prediction, or target designation. In practice, Soviet air to surface missiles use a radar command guidance mechanization for the whole course of missile flight. Survival of the reconnaissance vehicle, therefore, can be assured by reducing Soviet radar capability against it, or by providing vehicle performance beyond the intercept capability of the air defense missiles.

3. Much can be done in aircraft design and construction to minimize radar reflectivity. [redacted] on both the A-12 and the D-21. Very little information concerning success of the designs is available but indications are that the A-12 will approach its design goals in radar reflectivity. Even fewer data are available for the D-21 design, but based on size, we may expect that the D-21 will present from 1/4 to 1/2 the target presented by the A-12. A given radar will, therefore, achieve from 70 to 85 percent of its A-12 range against the D-21. Despite the anticipation of success in reaching design goals of radar reflectivity, recent studies show that early warning radars will have about 20% probability of detecting the A-12 when it rises above the radar horizon. Taking the most optimistic prediction of D-21 radar cross section, probability that Tall King early warning radar will detect the drone is 50% at approximately 200 nm and 85% at approximately 85 miles. It is safe to assume that, if the Soviet early warning net is operating at anything near its potential, neither the A-12 nor the D-21 will be able to penetrate without detection.

4. Assuming that detection is not, in it-self, a deterrent, we must consider Soviet capabilities for successfully attacking the reconnaissance aircraft. In A-12 studies of this problem, the following assumptions were made concerning Soviet SAM capability.

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Control System

TAB C

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a. There is no radar tracking error and no missile guidance error.

b. There is no angular limit on the tracking radar; i.e., the target tracking radar covers a hemispheric volume without limitations.

c. There are no fire control or guidance computer errors.

d. Missile launch can be accomplished as quickly as six seconds after the target comes within range of the target tracking radar.

e. The missile can reach the A-12 or D-21 operating altitude in 30 seconds and can maintain an average horizontal velocity of 2500 feet per second.

It is apparent that the assumptions are extremely generous to the defense, and represent a worse case so far as survival of the reconnaissance vehicle is concerned.

5. The capability studies have considered two target tracking radars, Fruit Set "A" and Fruit Set "B," and have exercised their capabilities against the A-12 with the assumption that design goals for radar reflectivity are met, and that these goals are exceeded by a factor of three. The results of the study and extrapolation to the D-21 are as follows:

a. Fruit Set "A" tracking range is not sufficient to permit an attack if the A-12 meets its reflectivity design goal.

MANNED ABILITY TO DEVIATE

b. If the A-12 exceeds its goal by a factor of three, Fruit Set "A" tracking range is adequate to attack, providing the A-12 course is offset less than 15 nm from the SAM battery.

c. Against Fruit Set "B," the A-12 track must be offset 21 miles to escape attack if reflectivity goals are met, and it must be offset 30 miles, if reflectivity goals are exceeded by a factor of three.

d. Even if the D-21 presents as much as half as large a target as the A-12, Fruit Set "A" will not have sufficient tracking range to permit an intercept.

e. Against Fruit Set "B" the D-21 will require track offset of 15 to 20 miles to avoid attack.

f. The permissible missile launch "window" is extremely small. For a track directly over the missile battery, for example, the time interval during which launch must occur, is of the order of 30 to 40 seconds. As the track is displaced, the launch window becomes proportionately smaller.

6. Summary

a. Neither the A-12 nor the D-21 can expect to penetrate Soviet territory without detection. PART TIME?

b. Survivability of either vehicle is dependent mainly on performance of missile battery target tracking radars.

c. Against Fruit Set "A," the drone cannot be intercepted, and although the A-12 can theoretically be attacked, the missile defense capability is marginal at best.

d. Against Fruit Set "B," the drone gains immunity with track offset of 15 to 20 miles, while the A-12 requires 20 to 30 miles offset.

e. All of the conclusions above are based on assumptions extremely favorable to the defense.

7. The operational survivability of a drone or a manned reconnaissance system is not solely a function of its vulnerability to attack, but also depends upon the precision with which it can be guided to avoid known defenses. In a manned aircraft, the pilot will be able to monitor his actual position and correct any errors developed by the automatic navigation equipment. The A-12 should be able to fly very close to a planned track which would give it greater immunity to interception.

The drone, on the other hand, will be guided by an inertial system which is not subject to correction after launch. The initial conditions at launch will also be subject to error. Present specification for the M-21 navigation system requires an error boundary of 2.8 nm which becomes the initial error for the D-21. Assuming that the D-21 inertial navigator will meet accuracy specified for the MH-330 system, further error accumulation will be at a rate of 1.5 nm per hour, standard deviation. For reconnaissance track planning, it seems reasonable to offset by at least two times standard deviation in order to insure a high probability of survival. Using root sum square combination of errors, and two standard deviations of navigation error, it would be necessary to offset the drone

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track by approximately 4 to 5 miles for probable guidance errors in addition to the offset required for theoretical immunity from SAM attack. With this consideration, there appears to be little to choose between the 20 to 30 miles standoff of the A-12 and the 20 to 25 miles standoff of the D-21.

RECONNAISSANCE SENSORS

1. The A-12, and D-21 are designed as photographic reconnaissance vehicles, while the R-12 is a multiple reconnaissance sensor vehicle. Direct comparison is possible only in the camera complement of the three vehicles and is presented in Table 1.

2. In addition to the cameras, the R-12 will carry the following reconnaissance equipment:

a. High Resolution Radar

Lateral Coverage - 10 or 20 mile swath at 20-80 nm right or left of track

Linear Coverage - 4000 nm

Resolution - 20 mile swath 50'
10 mile swath 30'

b. Infrared

Lateral Coverage - 28 nm

Resolution - 1 milliradian (85 ft at nadir)

Thermal Resolution - 0.5°

Linear Coverage - 6 hours (12,000 nm)

[redacted]

TAB D

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Characteristic	A-12	D-21	R-12 Terrain	 Operational	 Technical
Focal Length	21 in	28 in	6 in	12 in	48 in
Type	Panoramic	Step Frame	Frame	Panoramic	Step Frame
Coverage Lateral (nm)	41.3	36	21	34.4	34
					10
					5.3
Linear Coverage	3743	3020	8500	4000	100 targets
					19 frames ea or 2240 nm
Ground Resolution (ft) (1)	1.3	1.3	16.5	1.8	0.6

(1) All figures for ground resolution are design goals and are dependent upon achieving film-lens resolution of 120-160 ~~lens~~ lines/millimeter, and IMC of the order of .5 to 1.0 percent. ASD camera specialists predict operational values of 2 feet for A-12 and D-21 designs, 1+ for R-12 technical objective camera on medium contrast targets near nadir.

CAPSULE RECOVERY

No ops. pl an. — D-21.

1. It is intended that recovery of the D-21 reconnaissance data be accomplished by ejecting a package containing the camera, navigational system, electronic components of the flight control system, a beacon and command receiver. The total package weight is estimated at 880 pounds. Primary recovery will be by the air pick-up technique used for recovery of Discoverer payloads. In the event air pick-up is not successful, surface recovery is possible since the package is designed to float. SEA RECOVERY AFTER SECURED? OPS PROB.

2. The following information defines the Discoverer capsule recovery program and experience as it may apply to the D-21 capsule recovery effort:

a. The capsule weighs approximately 180 pounds, the 30.7 foot main chute deploys at 50,000 feet, the time-to-water from main chute deployment is 26.5 minutes.

b. For detection, a radio beacon is actuated at capsule separation, the chute has alternate orange and white gores and at chute deployment, a flashing light is turned on.

c. Based on a three-sigma dispersion, the primary recovery area is 20 x 140 nm.

d. Recovery forces consist of the following:

(1)

Aircraft	Required	Standby	Remarks
JC-130B	5	2	Capsule detection, air recovery and search
SC-54	1	1	Air rescue and surface retrieval by pararescue team

(2)

PMR Ships	Required	
Victory Ships	2	Detection, search, and surface recovery
Destroyers	1	Back-up surface recovery

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e. The JC-130B aircraft range for support of aerial recovery is 1100 nm with 3 hours on station. The aerial recovery range depends on the time from parachute deployment to pickup but is considered to be 70 nm for planning purposes.

f. The following chart depicts Air Force experience with capsule recovery:

Calendar Year	Capsules Separated	Capsules Re-entering Recovery Area	Recovery Air	Recovery Sea	Lost
1959	4	0	0	0	0
1960	6	5	3	1	1
1961	8	7	4	3	0
1962	20	20	16	0	4*
1963 (thru 15 Oct)	11	11	8	2	1**

SINGLE LOCATION

* One chute did not deploy, three attempts at air recovery damaged chute, capsules impacted in sea and sank.

** Power failure prevented chute deployment.

3. It is believed that the following conclusions can be based on applying the Discoverer experience to the D-21 recovery problem:

a. The larger weight of the D-21 recovery package (880 vs 180 lbs) may make aerial pick-up more difficult.

b. A significantly large fleet (aircraft and ships) will be needed for recovery operations and the beacon on the D-21 must radiate for a relatively long period to permit re-deployment of the recovery aircraft to within sufficient range of the capsule separation point if air pick-up is to be achieved.

MULTIPLE RECOVERY LOCATIONS

c. Most Discoverer capsule losses in the last two years were of a type directly applicable to the D-21 problem. This implies no better than an 84% probability of data recovery unless improvements in recovery technique and design reliability are achieved.

PRESENT RECOMMENDED PROG.

R-12 @ ONE/MONTH PROD. RATE

FY's	63	64	65	66	67		
AIRCRAFT	32.	160.9	259.2	221.5	69.3	—	743.4
SENSORS	6.3	34.9	60.8	59.4	22.5		
TOTAL	38.3	195.8	320.	280.9	91.8	—	926.8

*OPS. FIRST R-12 MAY 1965
TOTAL BUY = 31 = 6 TEST - 25 OPS
LAST OF 31 MAY 1967.