UNCLASSIFIED

[redacted]

[redacted]

"CONFIGURATION DESIGN FOR LOW RCS" (U)

September 1, 1975

John D. Kelly

Boeing Aerospace Company
Research and Engineering Division
Seattle, Washington

Information classified by competent authority has been removed from this document.

[redacted]

UNCLASSIFIED

ABSTRACT [redacted]

[redacted] The design of low radar cross section (RCS) aircraft and missiles requires major attention during the configuration design process. This paper reviews those features of airborne vehicle configurations that have a primary influence on the resulting radar signature. The RCS contributors are discussed in terms of three radar viewing sectors - nose, tail, and broadside. Measured RCS data are shown to illustrate the impact of design variables.

[redacted] An example is given of a design approach for achieving a low RCS configuration for a high altitude, air breathing missile.

LIST OF ILLUSTRATIONS [redacted]

CONFIGURATION DESIGN FOR LOW RCS [redacted]

John D. Kelly

Boeing Aerospace Company
Research and Engineering Division

I. INTRODUCTION [redacted]

[redacted] The RCS (radar cross section) properties of airborne type vehicles provides the major means by which they are detected and their location determined. Whereas, a large RCS is acceptable and even desirable for "friendly" situations, such as for commercial aircraft and target drones, low RCS is important for covert and military missions over the enemy's territory.

[redacted] RCS design for military aircraft and missiles has only received serious consideration in recent years. In the past, the RCS which have resulted have been relatively large requiring various techniques and tactics to obtain an acceptable level of survival. Recent design studies have included a moderate degree of RCS control during the preliminary design. These design studies have permitted the RCS to impact on the configuration to the extent that the performance (size, velocity, altitude and range) are not degraded. Future military airborne weapons will likely place more emphasis toward achieving very low RCS. In this regard, it will be necessary that the RCS have a major influence on the configuration and that some degradation in aerodynamics and propulsion may become necessary.

[redacted] Much of the RCS reduction studies for airborne vehicles is performed after the design is fixed or even after the vehicle is operational. This situation has severely compromised any real opportunity to attain low RCS because of the restrictions that are often imposed, such as, no cost or weight increase. This has created a reluctance to consider any changes to the configuration, such as, the external shape, engine inlets, engine exhaust, etc. Such an approach has, therefore, not permitted the state-of-the-art to be applied and has resulted in RCS reduction levels of 10 db and less. Radar cross section reduction studies have, therefore, resulted in levels of approximately 1 m^2 for manned aircraft and .01 m^2 for missiles.

[redacted] Achieving very low RCS for airborne vehicles, , is a reasonable goal. However, and this is very clear to the RCS specialist, this requires that the configuration must receive equal attention as other design factors, such as, performance. Interdisciplinary design studies are absolutely essential among those experienced in observables, structures, aerodynamics and propulsion to achieve practical designs with acceptable levels of survivability, cost, and reliability.

[redacted] This paper is directed at reviewing those aspects of the configuration that have an important influence on the RCS and more particularly on the attainment of low RCS signature. Also, other observables, such as IR, visual and acoustics, are important signatures which should be carefully considered during the configuration selection phase; however, these are beyond the scope of this paper. Realistically, the control of observables must be studied in an integrated design approach since it can be expected that the design concepts will interact upon each other.

[redacted]

[redacted]

[redacted]

II. GENERAL DISCUSSION OF RCS CONTRIBUTORS [redacted]

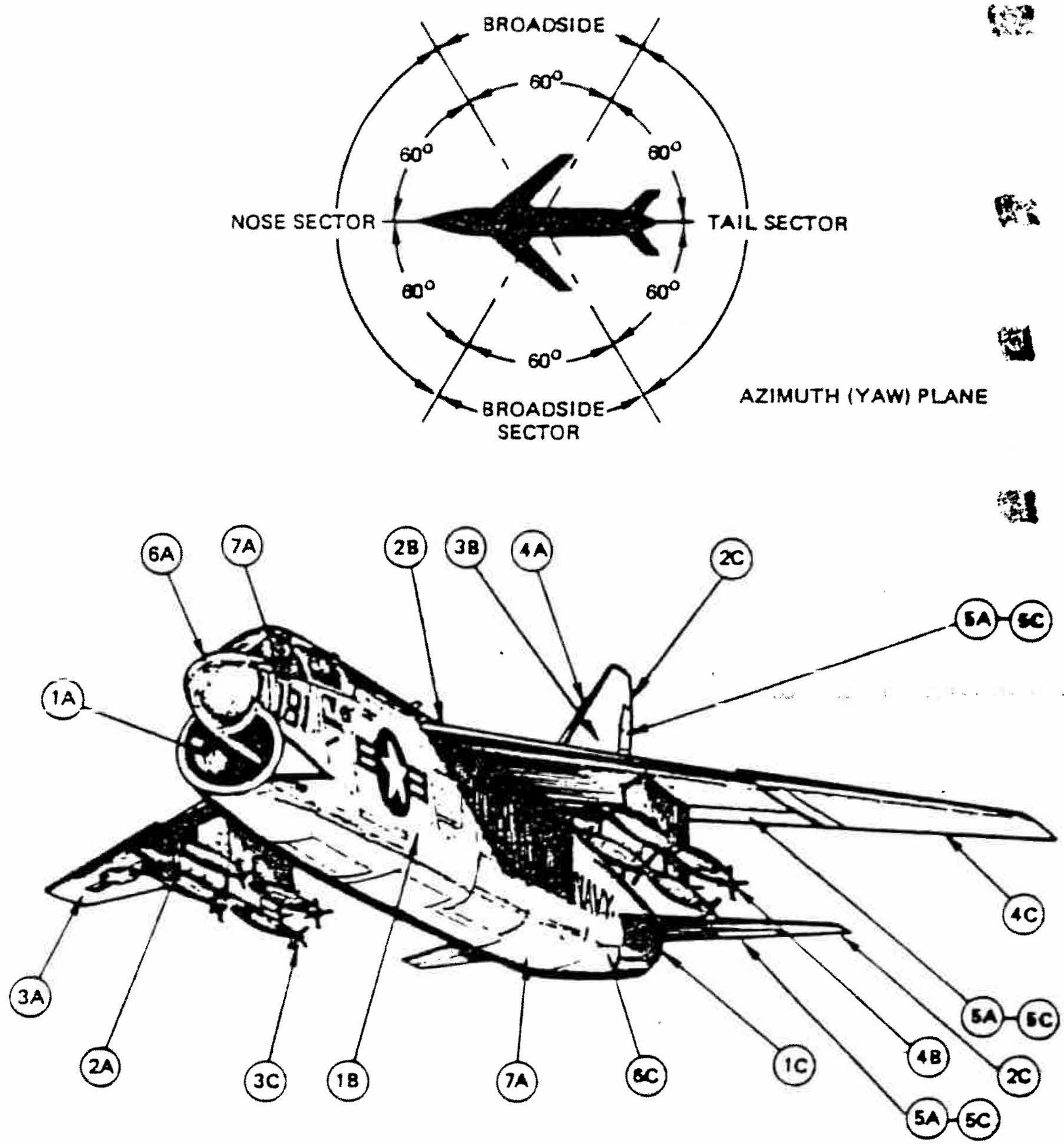
[redacted] Radar signature is of primary interest for the frequency band from approximately 1 GHz to 16 GHz. For most of the airborne vehicles, in this frequency region, it is generally accepted that the RCS signature can be determined by analyzing the major scatterers comprising the configuration. Therefore, in order to proceed in an orderly fashion with the design of low RCS vehicles, it is essential that we have an adequate understanding of the contributors which can make a significant contribution to the radar signature.

[redacted] Prior studies made of airborne vehicles exposed to enemy's threats have established tactics and countermeasure techniques that are necessary to achieve acceptable levels of survivability. These studies have led to a common practice in discussing the RCS of missiles and aircraft to assume three sectors about the vehicle - nose, tail, and broadside. Although there are no hard rules established, the nose, tail, and broadside sectors are often considered to be those shown in Figure 1 for the azimuth plane.

[redacted] The RCS contributors for the three sectors are shown in Figure 1 for a tactical type aircraft. Not shown on the aircraft may be numerous antennas, fuel pods, etc. that can be significant contributors. In the case of rocket engines not requiring an air inlet, a major contributor is deleted from the nose sector.

[redacted] The mentioning of these contributors is not intended to mean that they are of equal importance, rather that all of them must be considered if attaining very low RCS is a design objective for all azimuth angles. Many of the various contributors may be excluded if RCS controls are limited to one or two of the three sectors. Also, some contributors can be excluded if the specified levels of RCS are not greatly different (-5 to -10 db) from that of a conventional design. Also, it should be recognized that the RCS of existing airborne vehicles can likely be reduced in the range of 5 to 10 db by judicious treatments with RAM.

[redacted] Most of the RCS contribution for the nose region will result from the engine inlet - if air breather type, forward looking radar and ECM compartments, pilot canopy, nose, wing and empennage members, slots associated with control surfaces in the wings and tail members, and external stores. For low RCS design, the entire shape and all transitions are important.



NOSE SECTOR		BROADSIDE SECTOR		TAIL SECTOR	
1A	INLET	1B	FUSELAGE	1C	EXHAUST NOZZLE
2A	STORES	2B	WING LOCATION	2C	EMPENNAGE
3A	WING	3B	EMPENNAGE	3C	STORES
4A	EMPENNAGE	4B	STORES	4C	WINGS
5A	CONTROL SURFACES			5C	CONTROL SURFACES
6A	RADAR/ANTENNA			6C	FUSELAGE (TAIL, NOSE & TRANSITIONS)
7A	FUSELAGE (NOSE, TAIL AND TRANSITION REGION)				

Figure 1: RCS CONTRIBUTORS [redacted]

[redacted] For the tail sector, many of the same type of contributors mentioned for the nose sector apply. The exhaust nozzle represents a large cavity of major concern for this sector. Also, to be reckoned with are the wing and empennage members, tail, external stores, tail radar, and ECM compartments. Low RCS requires that the entire shape and all transition must be considered.

[redacted] The broadside region requires that the shape of the fuselage be given prime attention; also, the arrangement for the empennage and the wing/body must be considered. Engine nacelles can be important, as well as, the external stores.

[redacted] A few other contributors which may be overlooked are worthy of mention, such as: 1) Surface irregularities, like small ridges and gaps, and 2) Fiberglass surfaces, as skin material. As mentioned previously, the importance of some of the contributors may be trivial unless low RCS is a design requirement.

[redacted] This portion of the paper provides a familiarity with the various contributors that should be carefully reviewed in the configuration selection phase. The point that needs to be stressed is that if any of these are ignored during the configuration selection phase, it is unlikely that the configuration will be altered with the design process well along. The following section will discuss how one must proceed with the configuration design for attaining low radar signature.

[redacted]

III. CONFIGURATION DESIGN CONSIDERATIONS [redacted]

[redacted] As previously mentioned, the general RCS design approach is based upon breaking the configuration into the contributors that are important to the three sectors. The total RCS in a sector is estimated by summing arithmetically the median RCS values that correspond with each of the contributors. The RCS of each contributor can be determined through calculation or by measurement. RCS handbooks [1,2] provide valuable formulas and data that can be applied to many of the design problems. Large computerized programs exist for RCS calculation at many of the universities, DOD agencies, and aerospace companies that are involved with RCS studies. It is especially noteworthy to mention the Air Force developed program[3] which is probably the most sophisticated of the RCS computerized programs that exist today in the United States. Where unique data are necessary or where accuracy is essential, measurements can be performed on scaled models of the contributors or of the entire vehicle. Static RCS measurement of models for obtaining these data is presently highly developed.

[redacted] The discussion that follows considers each of the contributors as it pertains to the three sectors - nose, tail, and broadside.

A. Nose Region [redacted]

[redacted] For air breathing vehicles, the engine inlet is a major RCS contributor requiring close attention. The engine inlet is an electrically large, closed cavity. Essentially, all of the radar energy that strikes the aperture is scattered back in the general direction of the radar. Factors that should be considered regarding an inlet are its location, type, and features. The initial consideration should be the location whereby emphasis is given toward minimizing the visibility of the inlet aperture to the RCS sector. Following the location selection the type of inlet must be determined. Inlet features which should be considered are those which help "hide" the fan blades in the engine, curving of the inlet duct, long ducts, divider plates in the duct and aperture tilting.

[redacted] The location of an inlet impacts on the RCS control process. Data for the case of an inlet, mounted first inboard and then outboard along a wing surface is shown in Figure 2. The case for the inlet adjacent to the fuselage allows for absorber treatment of the fuselage forward of the inlet. This achieves an RCS reduction not available to the outboard location. The inlet location can be further exploited to achieve a low RCS. The selection of the inlet location should consider whether it is to be mounted on the top, bottom, or on the sides of the fuselage. Obviously, a top-mounted inlet, well aft, is a good choice where the RCS sector to be controlled is in the lower hemisphere. Conversely, the bottom-mounted location is a good choice where the RCS sector is in the upper hemisphere.

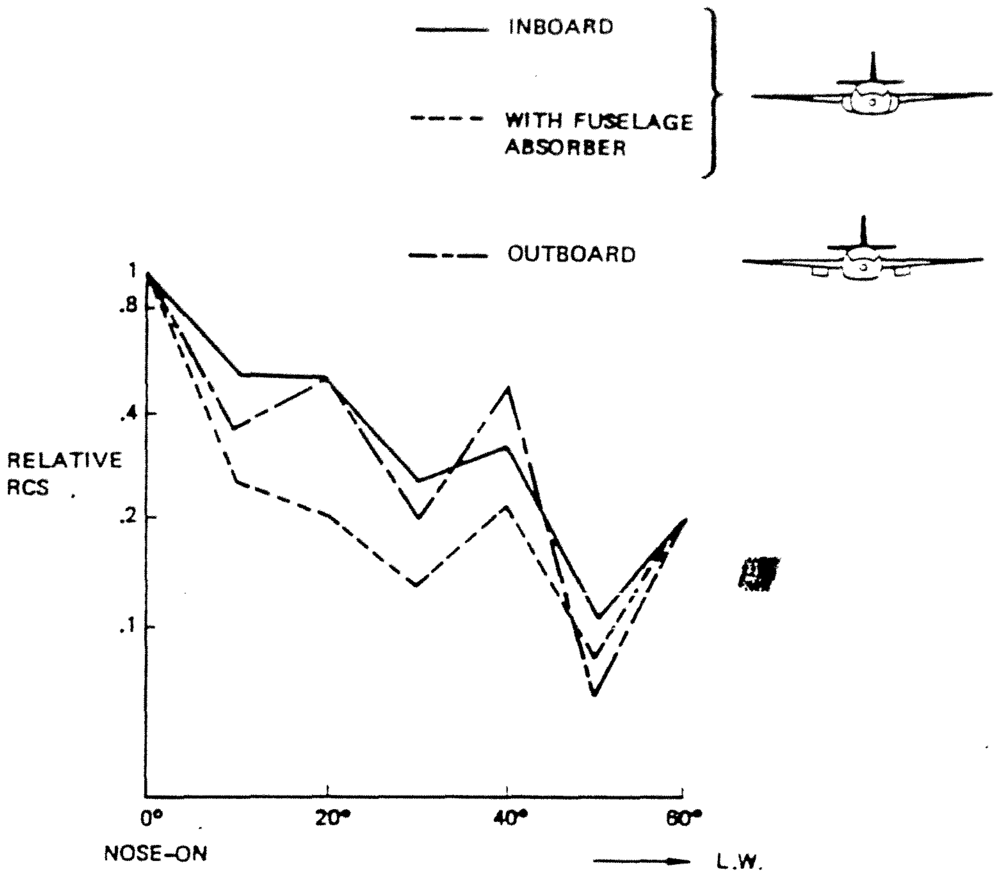


Figure 2 : INLET LOCATION RCS [redacted]

[redacted] A favored type of inlet for achieving low RCS is the plug inlet. Plugs exhibit lower RCS since they help scatter energy away from aperture and offer more absorber treatment per unit length of duct. Also, they help to hide the engine fan blades, which is a unique RCS contribution from inlets. Figure 3 provides for an RCS comparison of a plug inlet versus an "open" inlet type. The comparison assumes inlets of the same length and aperture area. The RCS advantages both with and without absorber treatment are clearly evident.

[redacted] Multiple inlets are preferred over single inlets since they can provide for more extensive absorber treatments. An additional form of the multiple inlet is the incorporation of divider plates within the inlet which allows for further absorber treatment. However, one must exercise some caution with this concept so that we do not carry this into the region where "cut-off" occurs. The "cut-off" condition must be avoided since it results in high reflection.

[redacted] For an inlet integrated into the fuselage, decreasing the height of the inlet by making it more conformal with the shape of the fuselage is useful for RCS. This stems from increasing the interaction between absorber lined metallic surfaces, as well as, decreasing the visibility of the inlet aperture.

[redacted] The RCS contribution from the nose region of the vehicle results from the tip radius, the general shape of the nose (often a cone or ogive), and the transitions between the nose and the fuselage. Figure 4 shows RCS data[1] for various nose parameters. The join contribution or transition should have the second derivative near zero when designing for very low RCS

The join contribution for the case of a cone/cylinder is included in the data for comparison with the other contributions.

[redacted] Low RCS designs must also consider the body shape, aft of the nose. Figure 5 displays the RCS for two shapes and the importance of the "base" radius.

[redacted] A forward radar compartment is commonly required on many of the airborne vehicles for navigation and fire-control purposes. A radome is installed over the radar compartment to provide an aerodynamic fairing. The "tuned radome" techniques[4] being developed by AFAL, in essence, provides for scattering properties similar to that for a metallic surface shape. Therefore, the shape of the radome is an important consideration. Although this paper does not cover the subject of the RCS for large aperture antenna types, a proper choice of the radar antenna is an important consideration during the configuration phase. A choice must be made between a compartment type antenna and a conformal type array. A conformal array exhibits low RCS features; however, the tuned radome approach is much further along in development.

[redacted]

2-5173-JDX-75-068

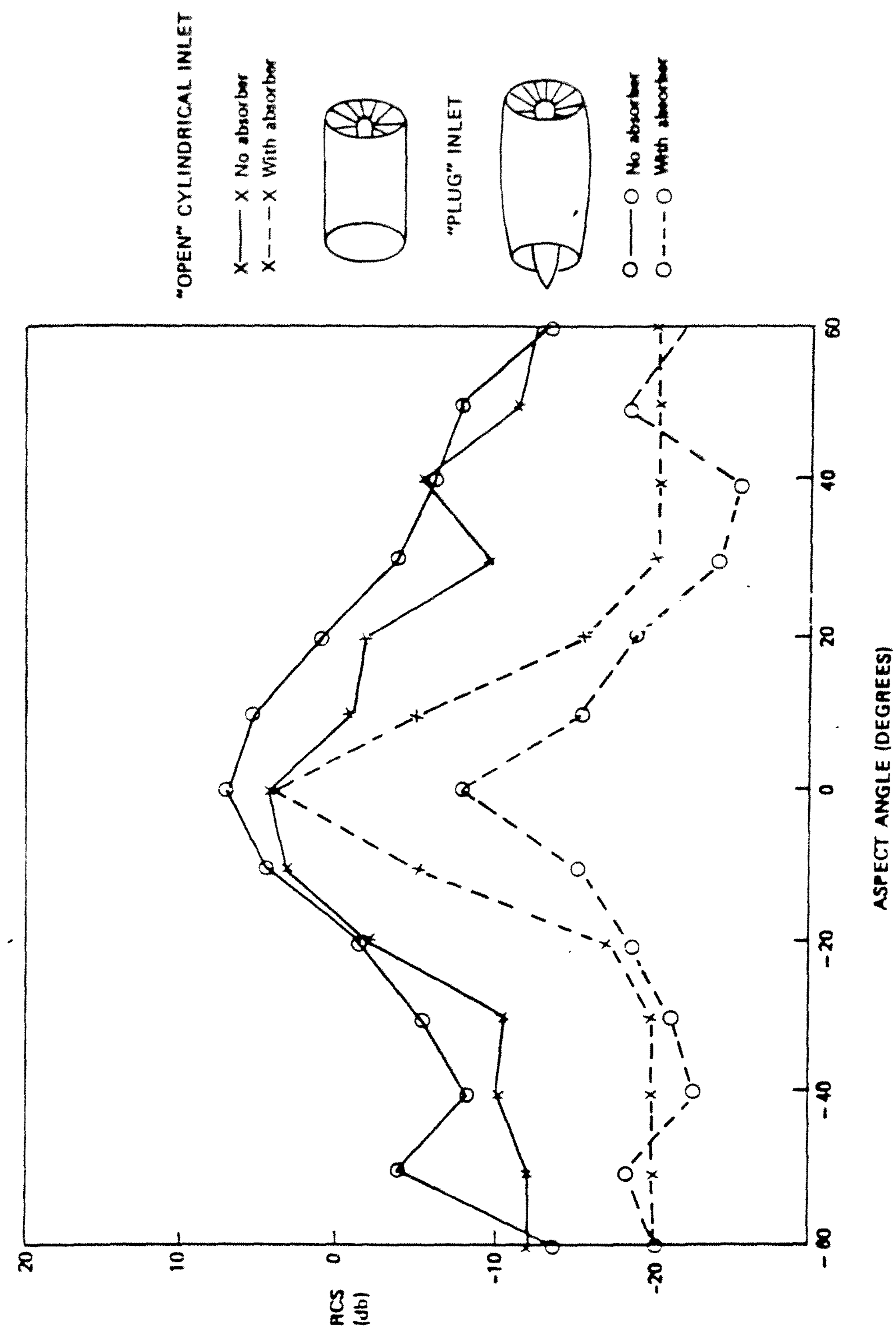


Figure 3 : RCS OF ENGINE INLETS

[redacted]

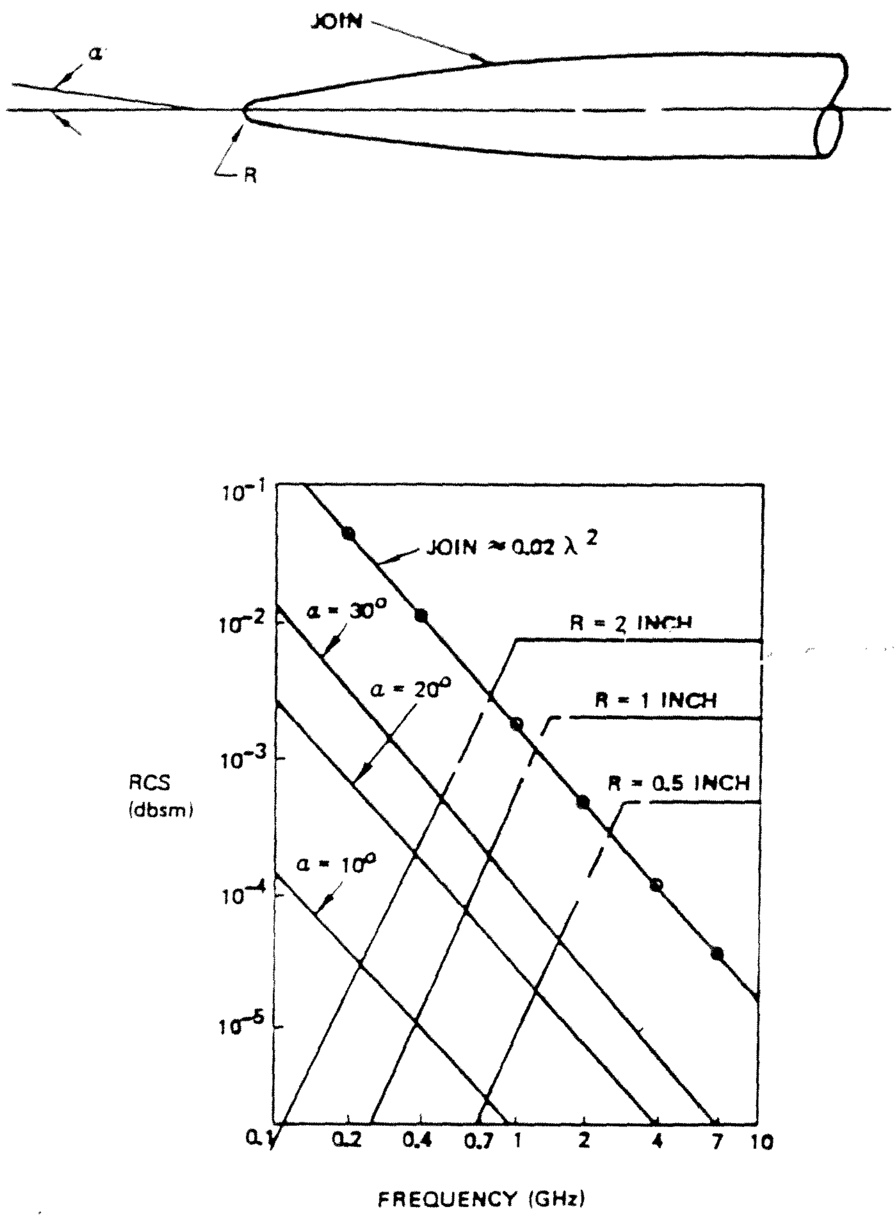


Figure 4 : RCS OF NOSE SHAPE [redacted]

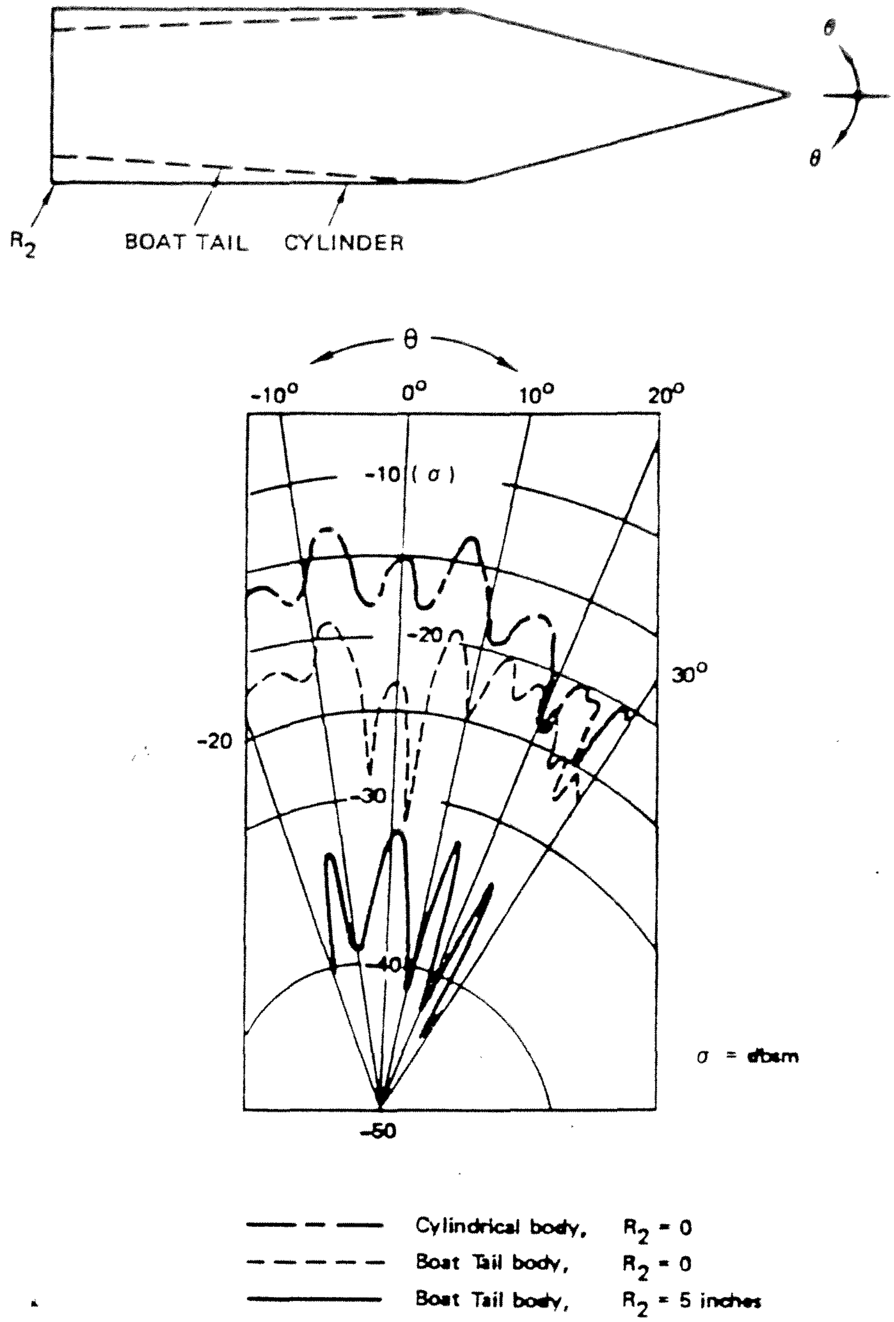


Figure 5: RCS OF BODY SHAPES [redacted]

[redacted] The wing and empennage members provide for both specular and traveling wave type of backscatter. The speculars are typically high level of RCS, often only a few degrees wide in the major plane and broad in the orthogonal plane. Sweeping of the wing and empennage members, both trailing and leading edge surfaces, can be used to move the speculars outside the RCS sector. Sweeping the edges can also be used to more evenly distribute the RCS throughout the sector so that the median levels of RCS are maintained at lower values.

[redacted] The nature of the RCS return for wing and empennage members[5] can be seen by measured RCS data of Figure 6 for a vertical tail. In the region of ± 60° about the nose, three types of backscatter are experienced: 1) specular from the leading edge-oriented at the nose, 2) traveling wave return adjacent to the edge specular, and 3) physical optics contribution adjacent to the traveling wave returns.

[redacted] The gaps associated with control members located in the wing and empennage members produce a significant increase in the RCS compared to a smooth member.[5] Shown in Figure 7 are measured RCS for a vertical tail comparing a "detailed model" (with gaps) with that for a smooth model. It may be feasible for some airborne vehicles to eliminate the control surfaces by employing thrust vectoring in the exhaust.

[redacted] External stores, such as weapons, pods, fuel tanks, are important RCS contributors that should not be overlooked in the design process.[6] Since weapons probably have the largest impact on RCS, this matter will be discussed. Pylons are commonly employed to hold clusters of bombs and missiles resulting in significant levels of RCS. The increase in RCS due to clustering or grouping not only is due to the numbers but is also due to multiple reflections or interactions among them. Guided bombs are now being developed having infrared and optical guidance systems which also can be expected to increase the levels of RCS.

[redacted] Clearly, the weapon carriage concept for RCS must consider the wide range of weapons that may be required on the airborne vehicle. An initial approach which should be considered is that of reducing visibility of weapons to the RCS sector, such as that discussed earlier for inlets. Weapon carriage concepts such as conformal weapon carriage, offers a viable approach, by hiding weapons to the maximum feasible extent. Concepts for hiding the weapons should be emphasized since little, if any, has been done to develop low RCS bombs. Shown in Figure 8 are measured RCS data[6] for 6 MK-82 bombs in both the conventional pylon mounts of twin TER (triple ejection racks) and a conformal carriage. The advantages of conformal carriage will be even more pronounced when the convenience of RCS control treatments, such as fuselage-mounted shields and absorber treatments, are utilized.

176

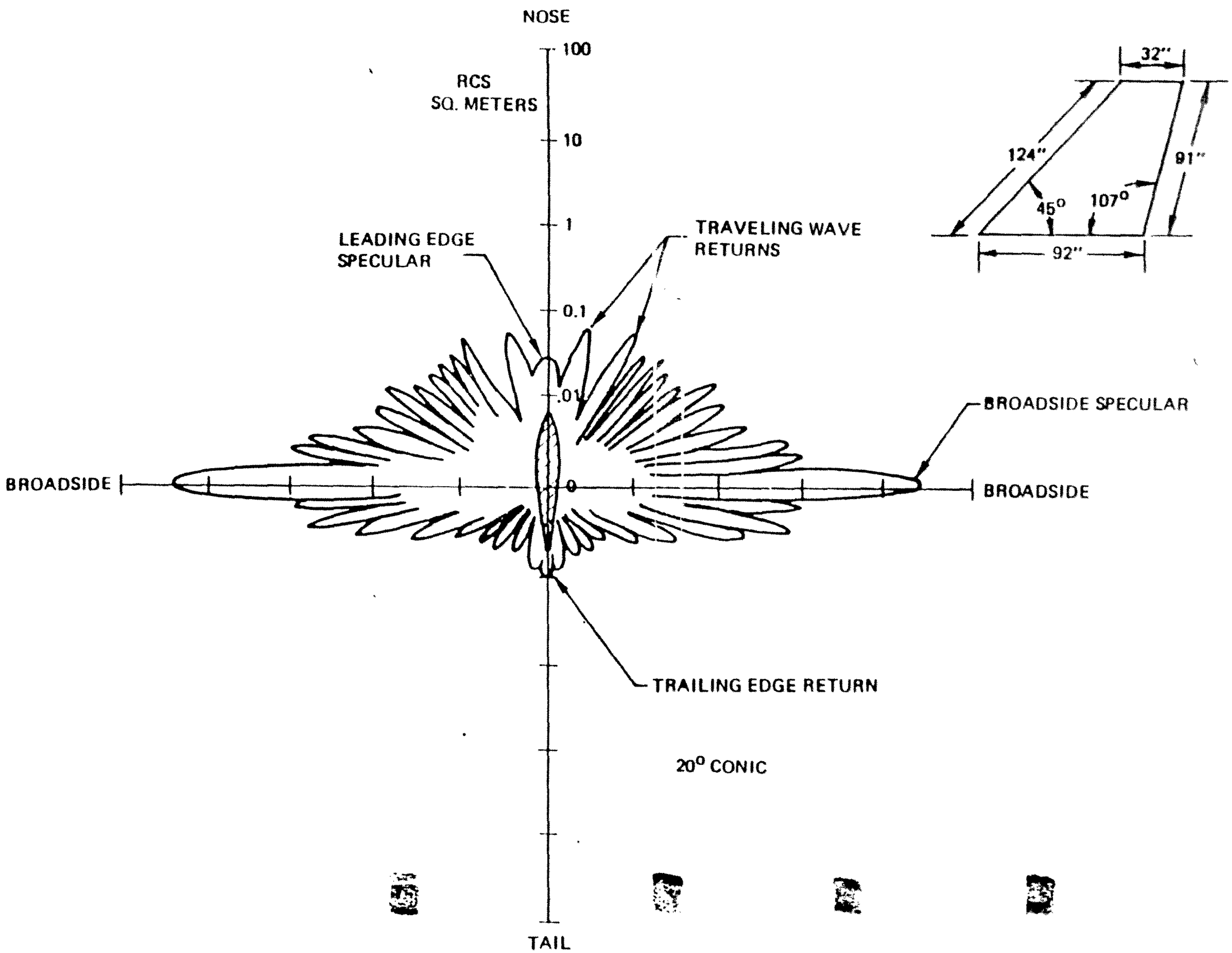


Figure 6: RCS CHARACTERISTICS OF VERTICAL TAIL [redacted]

2-5173-JDX-73-066

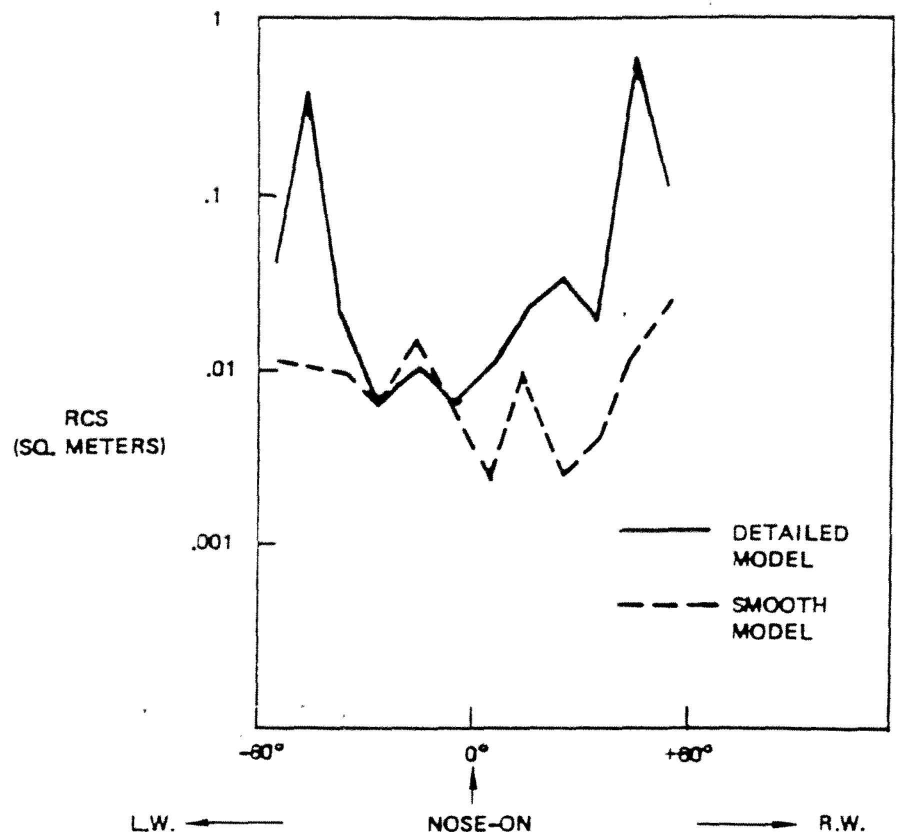


Figure 7: RCS FROM CONTROL SURFACES [redacted]

[redacted] 2-5173-JDK-75-068

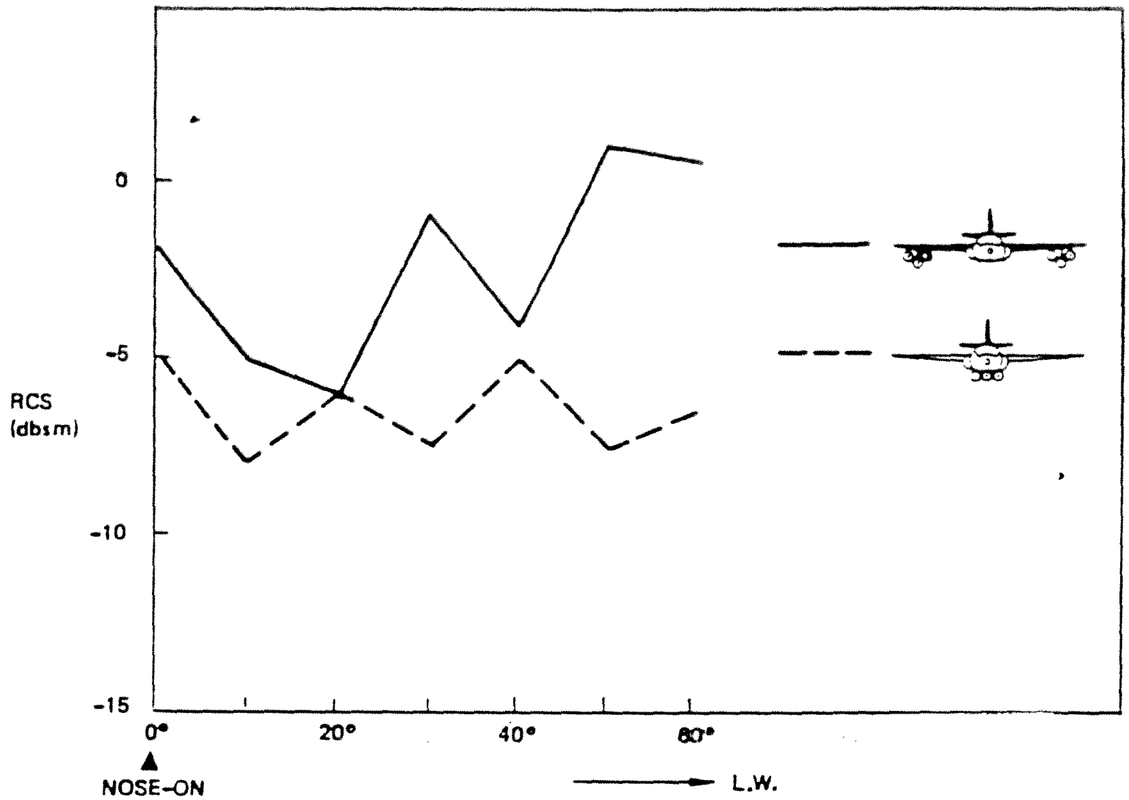


Figure 8 : RCS OF WEAPON CARRIAGE CONCEPTS [redacted]

[redacted]

B. Tail Region [redacted]

[redacted] The RCS design for the tail sector has much similarity to that for the nose. The RCS contributors which must be considered include the exhaust nozzle which is a major item and the tail shape, empennage members, and external stores.

[redacted] The exhaust nozzle configuration, together with its engine, is an important consideration for a low RCS design. Emphasis should be placed on designs which can reduce the severity of the environment, and therefore, allow more effective RCS treatments to be incorporated. These designs would also provide additional benefits to the IR and acoustic signature. The nozzle, like the inlet, should emphasize location, type and features for low RCS. Regarding the type, plug designs generally offer an advantage over the "open" type. Making the nozzle both long and curved provides similar advantages as for the inlet treatment and for reducing the blade contribution. Not to be overlooked during the configuration phase are nozzles which can readily provide cooling of surfaces for aiding in the design of RAM treatments. Cooling could allow presently available plastic materials to be applied, as well as, many magnetic materials, which are unsatisfactory at high elevated temperatures.

[redacted] A nozzle design which has been developed and which offers both RCS and IR benefits is the Two Dimensional Nozzle.[7] A 2D type nozzle design offers significant RCS improvement compared with the convergent type nozzle. Figure 9 displays measured RCS data for these two types of nozzles. Air for cooling can be introduced into the plug portion of the nozzle and is shown in the cut-away sketch of Figure 10. The 2D nozzle is an example of a nozzle design which specially addresses observables as an major design factor.

[redacted] Another consideration concerning exhaust nozzle designs worthy of mention is thrust vectoring in the nozzle region which can eliminate control surfaces in the wings and tail members. The gaps associated with control surfaces are significant contributors for RCS design below 1 sq. meter.

[redacted] The wing and empennage members provide RCS characteristics in the tail sector similar to those for the nose sector. In this regard, the sweep angle of the trailing edges must be given attention and a choice made. The gaps associated with the control surfaces are very important.[5] Figure 11 provides the measured RCS for a full-scale vertical tail, with and without incorporation of the control surface gap. The importance of gaps is quite clear. Elimination of control surfaces is a consideration that should be examined for low RCS designs.

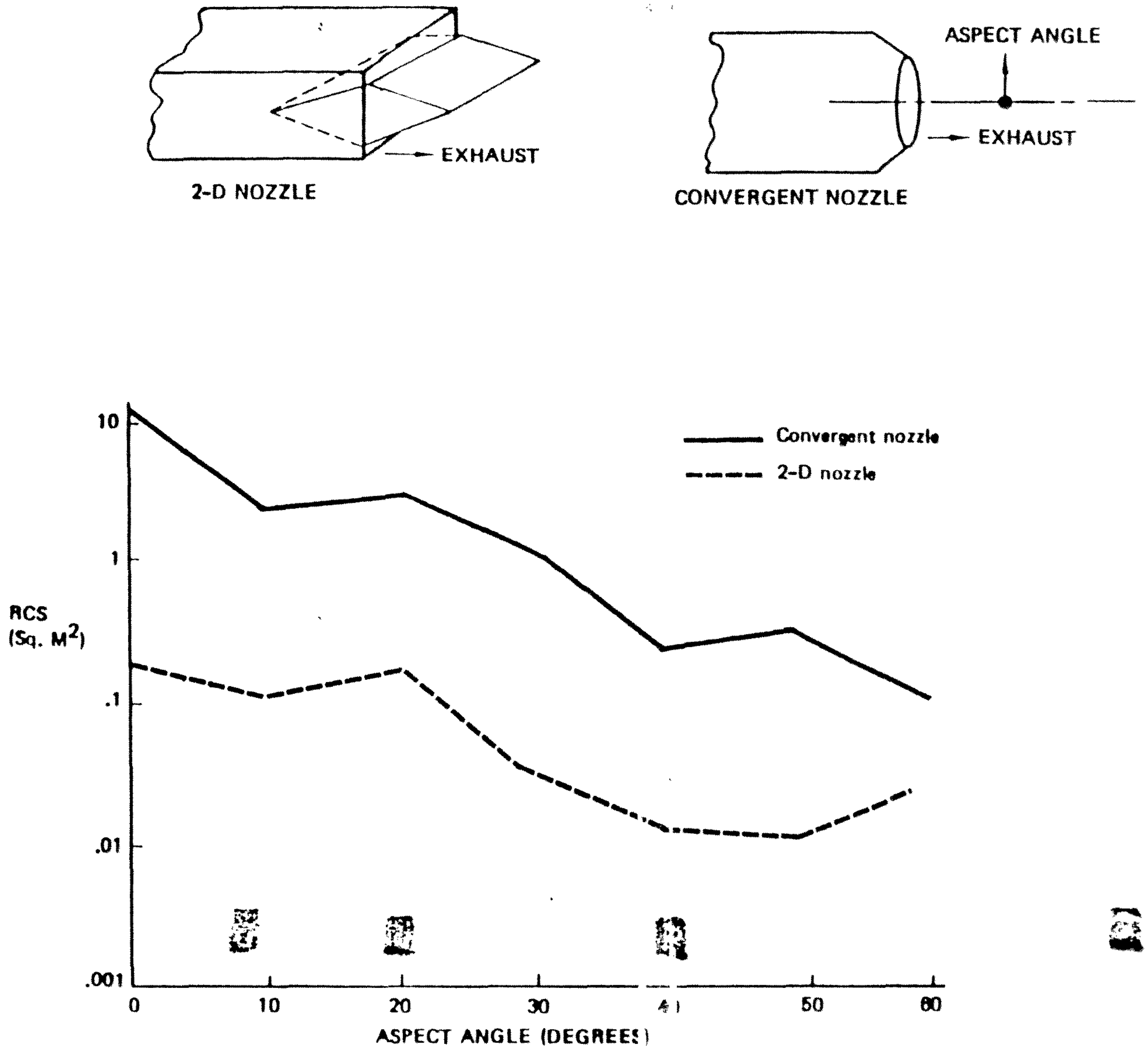


Figure 9: RCS OF EXHAUST NOZZLES [redacted]

[redacted]

[redacted]

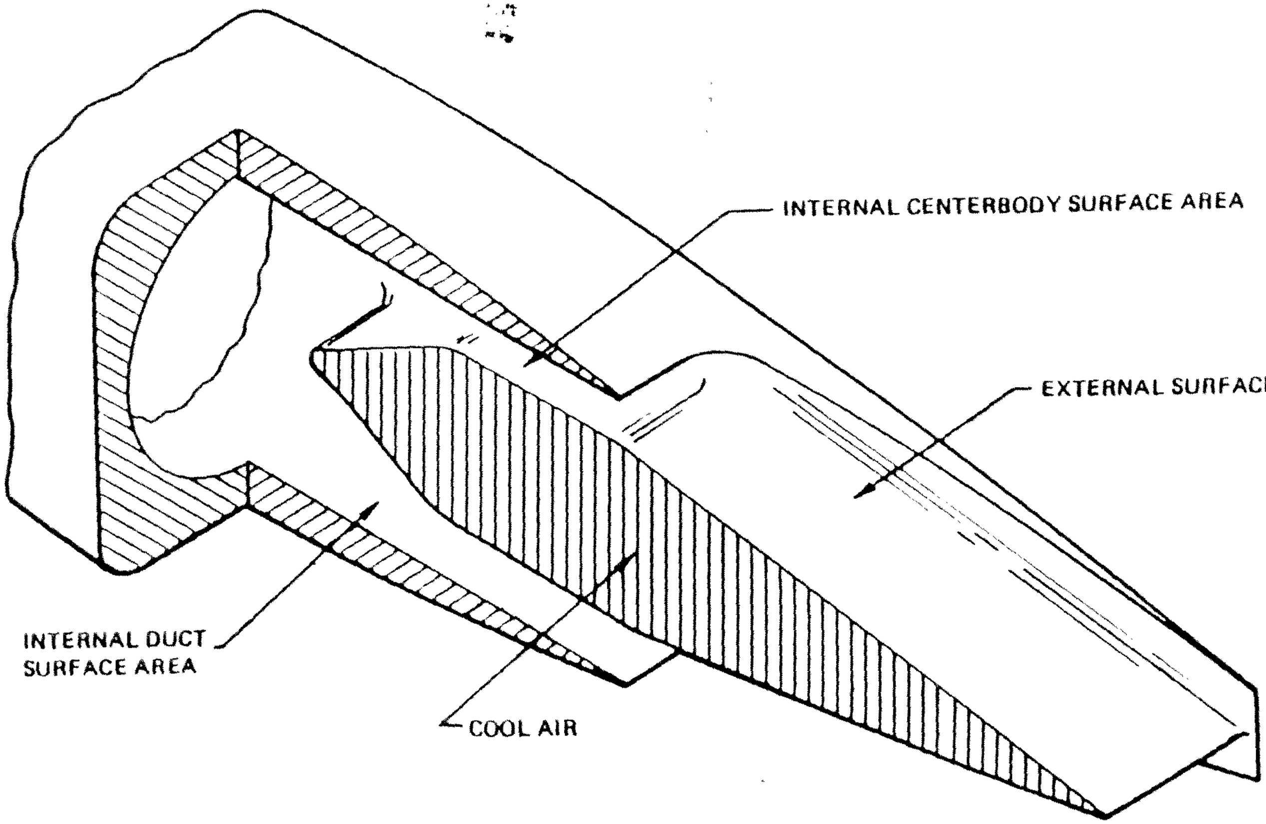


Figure 10: 2D NOZZLE [redacted]

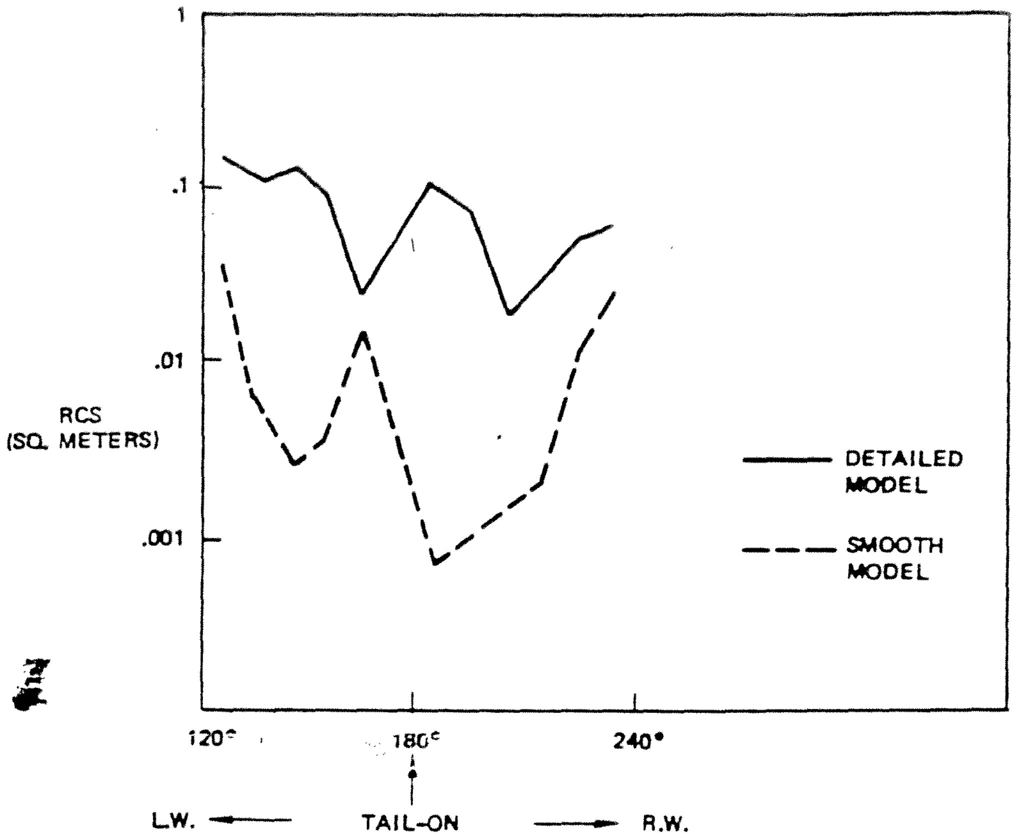


Figure 11: RCS FROM CONTROL SURFACES [redacted]

[redacted]

[redacted] The RCS resulting from store arrangements is also an important design decision impacting on the RCS in the tail sector. The subject of weapon carriage concepts is an important matter and requires attention for similar reasons discussed under the nose sector. Shown in Figure 12 is the RCS for two TERs (triple ejection racks) with 6 MK-82 bombs.

C. Broadside Region [redacted]

[redacted] RCS design for the broadside region has received little attention to the present time. The rationale being that the very high levels of RCS exist for only short periods of time and therefore do not provide sufficient reaction time for the enemy radars to utilize this characteristic. The development of improved weapons by the enemy most likely will necessitate that the broadside RCS receive consideration in the future.

[redacted] The RCS in the broadside sector is largely controlled by the fuselage, empennage members and the wing/fuselage joins. Additional contributors can be engine nacelles, external weapons fuel tanks, side looking radars, etc. Typical RCS characteristics of various airborne vehicles in the broadside sector are shown in Figure 13. These vehicles are operational systems which are presently found in our military inventory. Data in the figure show the 10° median RCS levels range from 3 dbsm (2 sq. m^2) for missiles to about 36 dbsm (4000 sq. m^2) for bomber aircraft.

[redacted] The fuselage shape is a major consideration in attaining low RCS. The shape must be selected to provide low RCS signature in the specified region, such as below or above the vehicle. A fuselage having flat sides will produce very large RCS amplitudes that range as high as several thousand sq. meters. A flat surface has the effect of concentrating the RCS in the vicinity of the normal to the surface. The RCS will vary greatly with change in angle, with the plane of longest dimension exhibiting most sensitivity.

[redacted] The flat-sided fuselage must generally be considered as an undesirable shape. The RCS characteristics for a "flat" fuselage/wing model are shown in Figure 14.[8]

[redacted] The circular cylinder shape also provides a large RCS although not as great as for the flat-sided fuselage. The RCS in the vertical or roll plane being essentially independent of angle.

[redacted] By going to the more blended type of shapes, such as elliptical, diamond and triangular, we can produce significant changes in the RCS. For instance, triangular shaped sides have the effect of moving the flat-plate type of return to the vicinity of the surface normal. The RCS data of a triangular-shaped fuselage for comparison with that for a flat-sided shape is shown in Figure 14. Also shown in Figure 14 are measured RCS data for an advanced

[redacted]

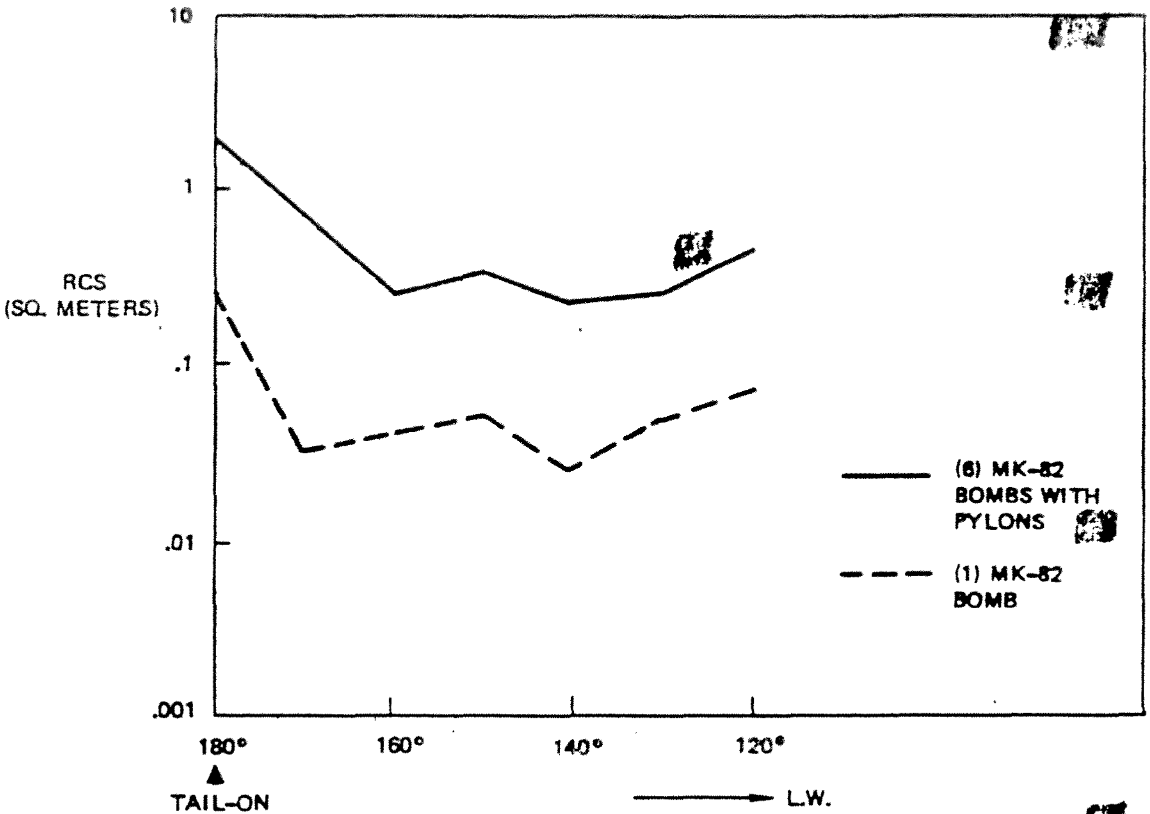


Figure 12: RCS OF WEAPONS [redacted]

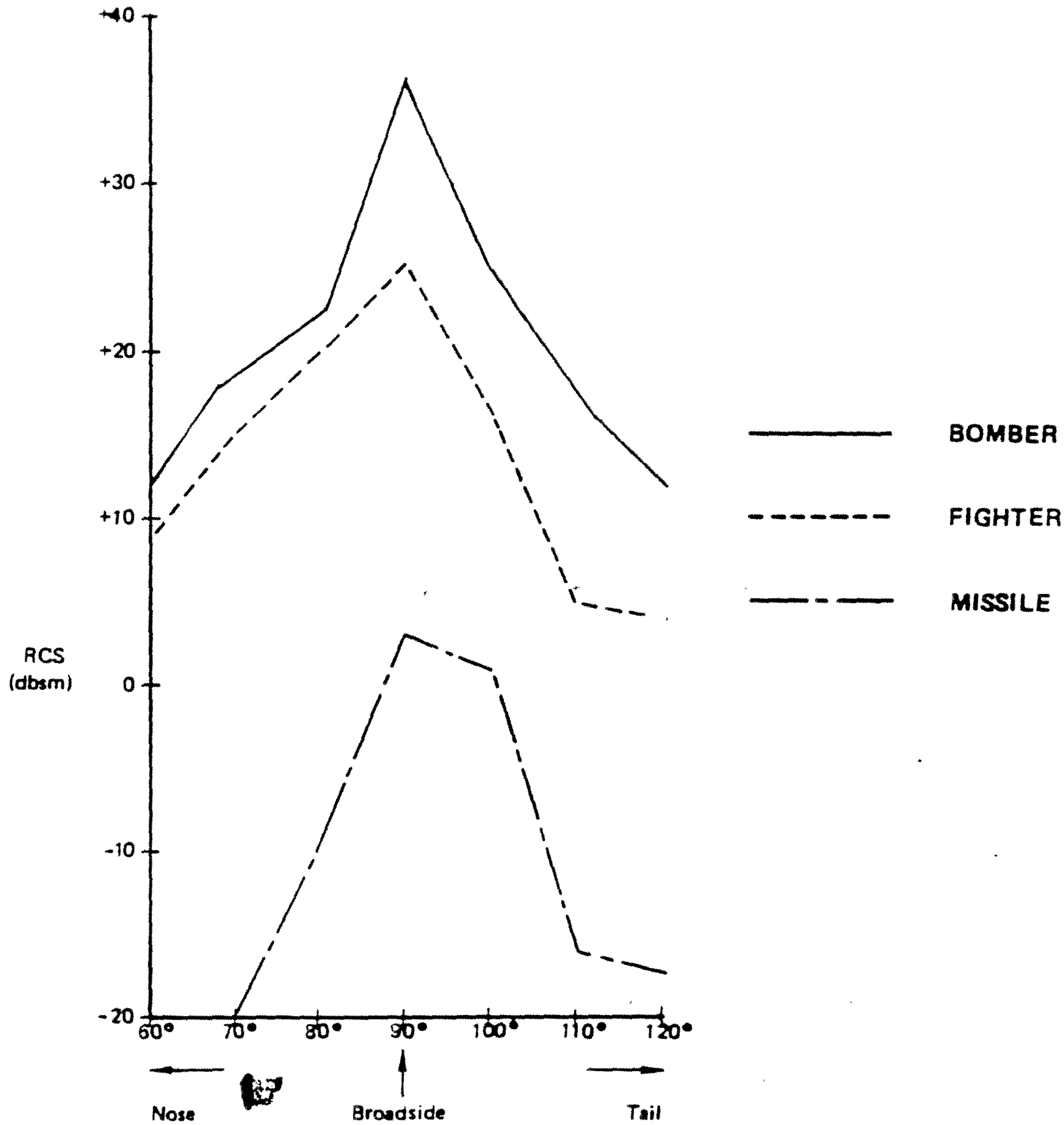


Figure 13: BROADSIDE RCS OF AIRBORNE VEHICLES [redacted]

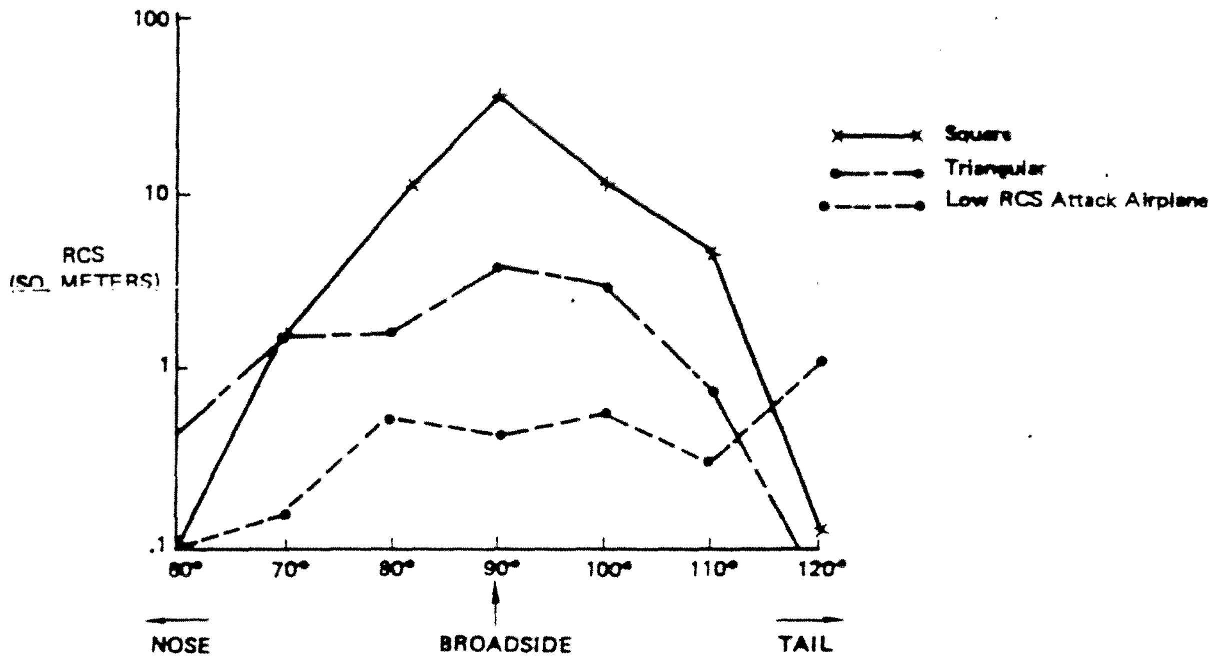


Figure 14: RCS OF FUSELAGE SHAPE [redacted]

[redacted]

[redacted] tactical fighter incorporating a degree of blending that does not produce any degradation in the subsonic/supersonic aerodynamics.[8] An extreme limit of the blending for a fuselage would be equivalent to that of a flat-plate where the major scatter would be located directly above and below the vehicle. The RCS in the broadside region would become essentially that from an edge type of return.

[redacted] The location of the wing has a strong RCS effect in the broadside sector. A major contribution primarily stems from the corner reflector created by the wing/fuselage junction. Corner reflectors provide large RCS levels over wide angles, and therefore must be avoided for regions of RCS control. Figure 15 displays some trend data for two wing positions as it impacts on the RCS, 30° below the airplane.[8] The advantage of a bottom-mounted wing is obvious. The "bottom-mounted" wing places the corner reflector return above the vehicle while the top-mounted places it below. A mid-mounted wing provides such a return both above and below.

[redacted] The arrangement of the empennage is important since it can be represented by a combination of flat-plate surfaces and corner reflectors. The usual vertical-rudder and horizontal stabilizer arrangement exhibits high RCS speculars in the broadside sector and a corner reflector contribution in the upper sector. By employing twin tail arrangements, major changes can be made in the RCS. The RCS characteristics of a conventional empennage arrangement and a twin-canted configuration are shown in Figure 16 to help demonstrate RCS characteristics which can be made to occur by these design approaches.

[redacted] Integration of engine inlets into the fuselage is important for achieving low RCS in the broadside sector. The importance of this design aspect is illustrated in Figure 17, which shows the RCS data for the case of a single engine nacelle with pylon.[9]

[redacted] An improvement which can help reduce the RCS in the broadside sector is based upon using multiple engines rather than a single one. By employing multiple engines, such as side by side, the height of the fuselage can be lessened, providing less effective area for scattering. In addition, a greater degree of blending can be incorporated which will help reduce the RCS in the broadside region. This is a feature of the advanced tactical fighter concept whose broadside RCS characteristics are shown in Figure 14.

D. Skin Material [redacted]

[redacted] Presently, most of the skin material for the external surfaces on airborne vehicles are largely metallic with the exception of radomes which provide aerodynamic fairings. Advanced composites, such as the graphite and boron fibers in their present form, exhibit a characteristic at microwaves which is equivalent to that of metal.

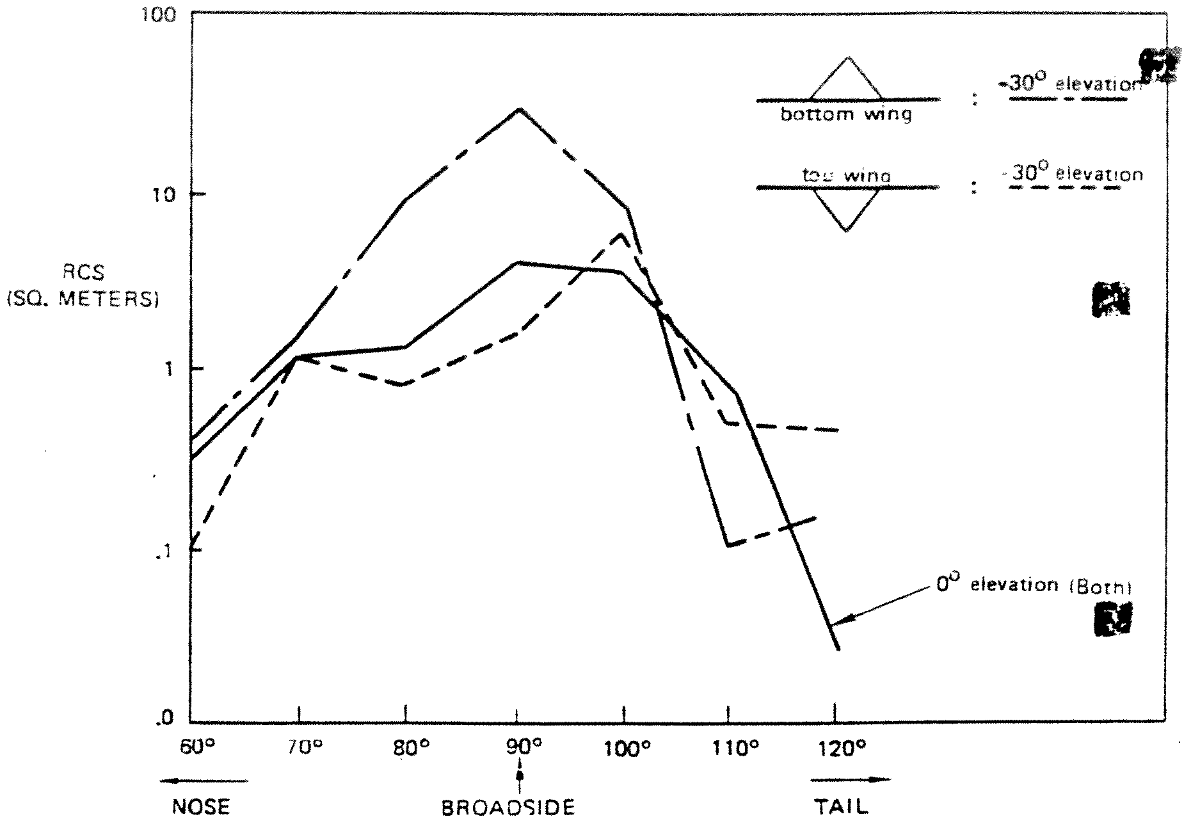


Figure 15: WING LOCATION RCS [redacted]

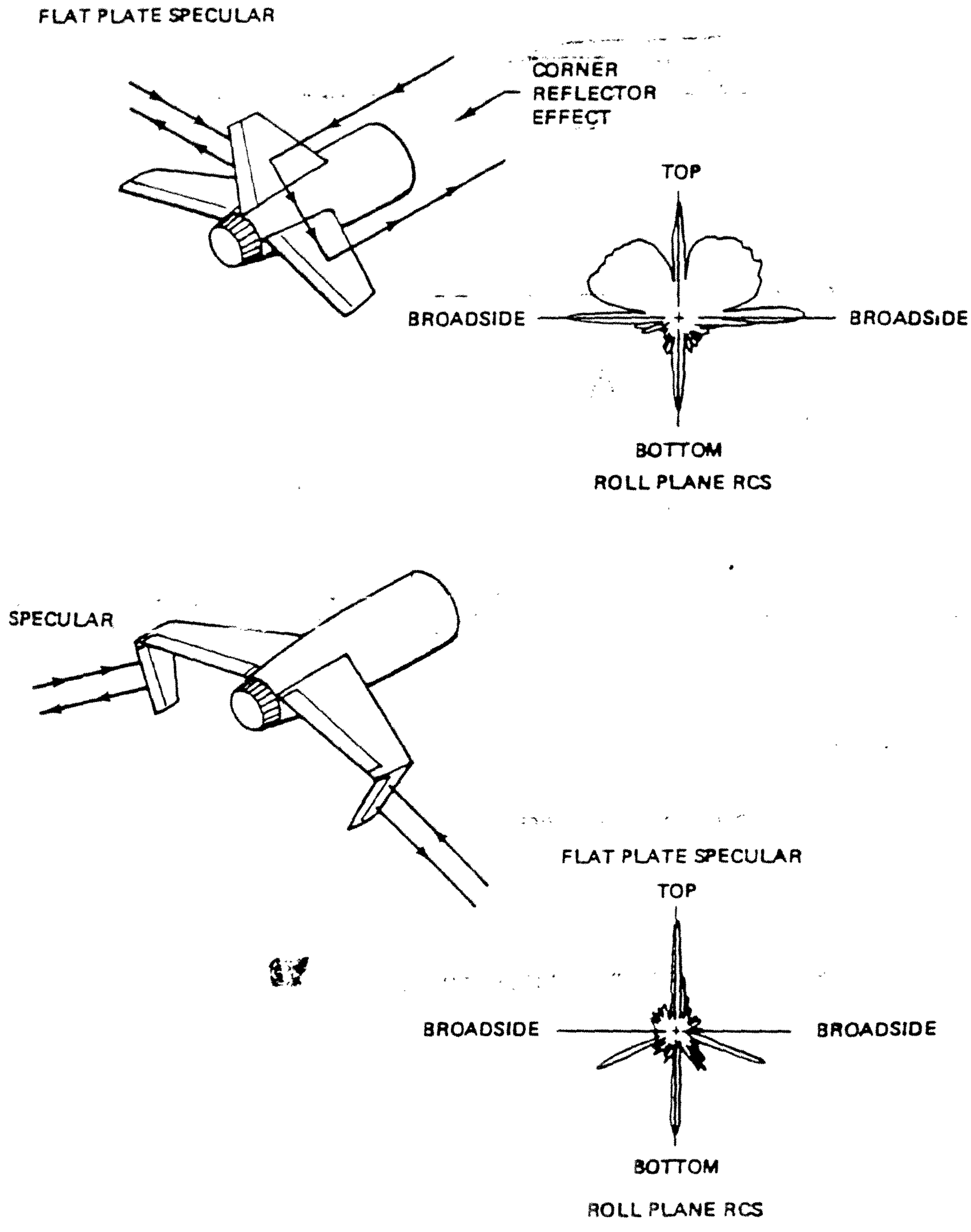


Figure 16: RCS CHARACTERISTICS OF EMPENNAGE [redacted]

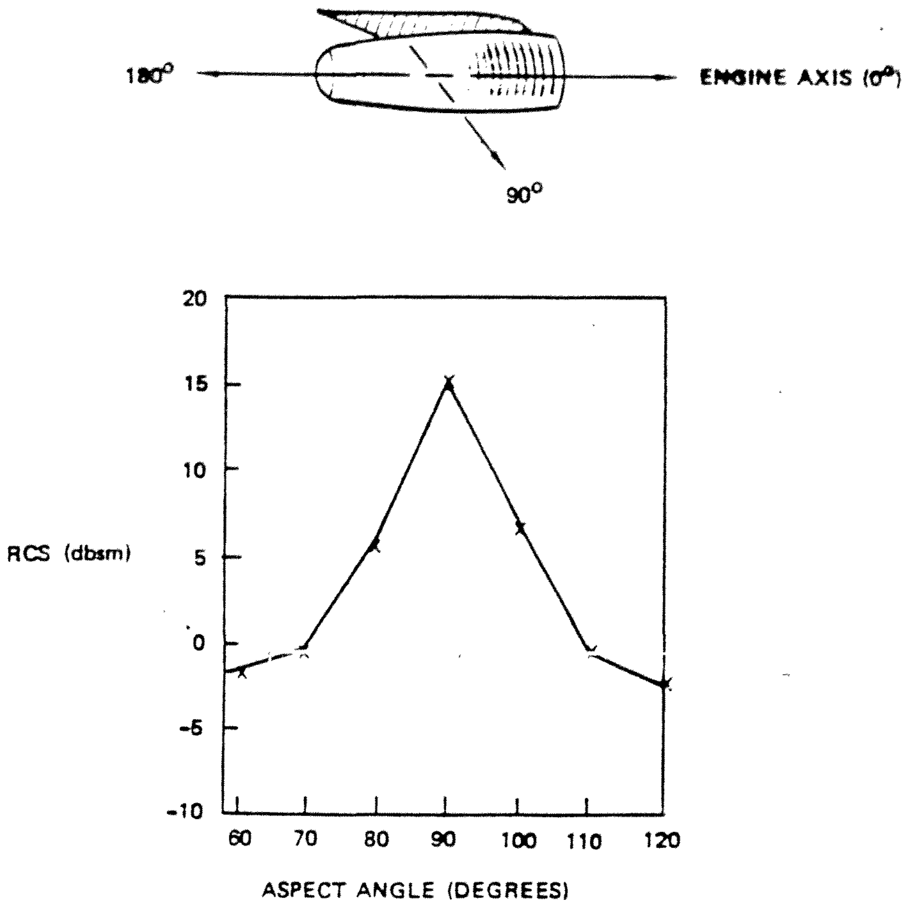


Figure 17: ENGINE NACELLE RCS [redacted]

[redacted] Skin surfaces made from fiberglass are being used in aircraft and missile designs for achieving cost savings in making complex shapes, etc. For aircraft and missile designs using plastics for portions of the skin, high RCS levels have usually resulted. An example of this is shown in Figure 18 which compares a wing design made from a metal and from fiberglass.[10] The dielectric wing is made entirely of fiberglass. The results such as these have created a bad impression for the usage of plastic structures in low RCS designs, which is unfortunate. In fact, external surfaces made of dielectric materials appear to be the optimum approach in some instances for achieving low RCS designs.

[redacted] The effective usage of dielectric materials in low RCS design requires an understanding of the nature of the electromagnetic waves whereby one can determine the scatter properties at in, and through the material. Unless this understanding is properly applied, it is likely that the backscatter in most instances will be greater than that of metallic surfaces.

[redacted] Dielectric materials provide an excellent opportunity to aid in low RCS designs s demonstrated in the Air Force SRAM missile. Particularly for the case of where surface waves are a prime source of backscatter, designs based upon dielectric materials are practical low RCS concepts. Dielectric materials used to support surface waves, incorporating small amounts of magnetic absorber, are effective in attaining low RCS. An example of a dielectric approach based upon the excitation/ absorption of surface waves is shown in Figure 19 for the case of a SRAM fin.[11]

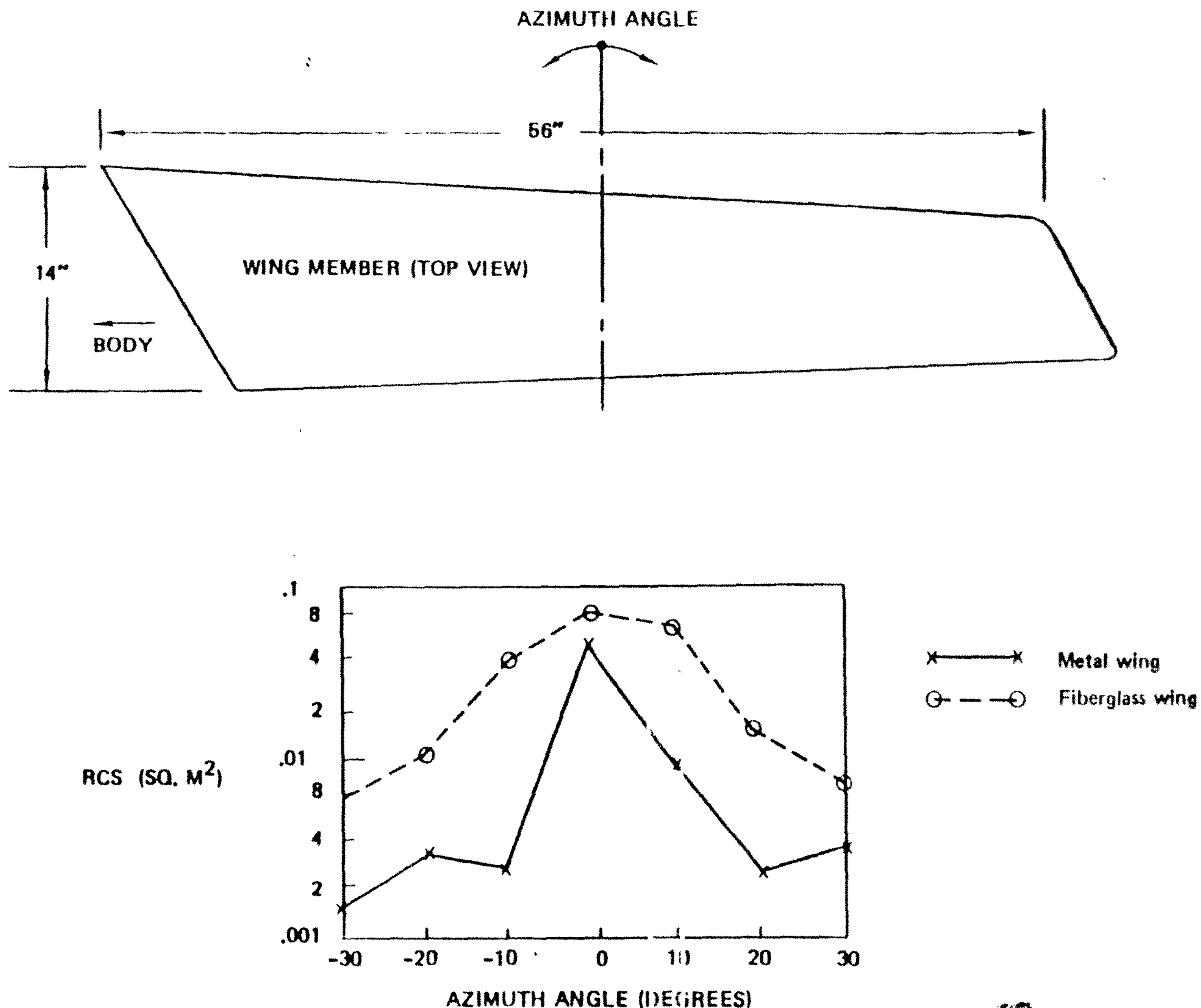


Figure 18: RCS COMPARISON OF METALLIC VS. FIBERGLASS WING [redacted]

2-5173-JDK-75-068

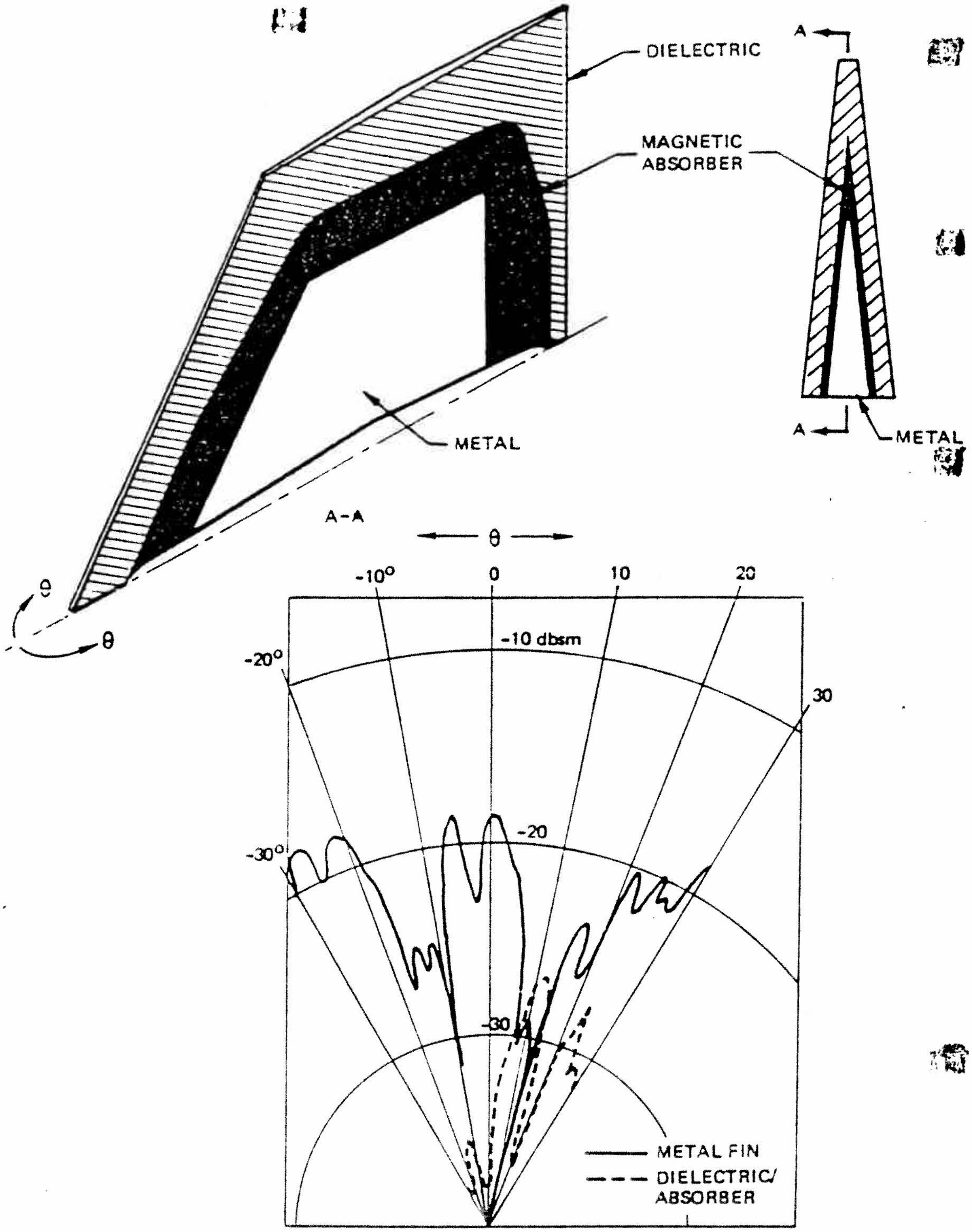


Figure 19: LOW RCS FIN DESIGN [redacted]

DESIGN OF LOW RCS MISSILE [redacted]

[redacted] The design of low RCS vehicles requires close attention to the RCS requirements which specify the region, frequency range and RCS magnitudes. Depending upon the severity of the RCS specification, there may be little or a great amount of latitude in the design of the configuration. RCS requirements below 1 sq. meter for manned aircraft and .01 sq. meters for missiles should require consideration of the configuration.

[redacted] Consider for example, the design of a missile with wings, where a low RCS configuration is desired. For this example, lets assume that the missile is an air breather type, 15-20 feet long, and flys at an altitude of 75,000 feet. For high altitude penetration, at least for the present, we could reasonable assume that RCS control is required only in the region below that of the missile, perhaps from 0 to -60° in elevation relative to the missile, and 360° in azimuth.

[redacted] Based upon the RCS sector to be controlled, several ideas are immediately suggested. The engine inlet and exhaust nozzle are located on the top-side of the missile and their apertures "hidden" from view to the RCS control sector. Proceeding further with the design, the inlet is made nearly conformal to the top surface and a long, curved inlet duct is used. A low RCS type of 2D nozzle is shown for the exhaust nozzle. Thrust vectoring is used in the exhaust nozzle, thereby eliminating the flaps in the wing and empennage surfaces. The fuselage is of a triangular shape with a flat, bottom surface. This would result in the specular for the bottom surface being located directly below the missile. The wings are bottom-mounted, flush to the bottom of the fuselage. This will move the corner reflector effect associated with the wing fuselage join to the region above the missile. Also, the specular from the bottom surface of the wing will occur directly below the missile. The empennage design consists of a horizontal stabilizer with a canted, twin tail. This configuration will result in both the speculars and corner reflector returns being located above the missile. The shape of the nose and of the tail portions of the missile are triangular with smooth, transitions used into the fuselage. The tips of the nose and tail are essentially sharp, low radius. The leading and trailing edges of the wing and empennage members are swept to move their speculars away from the vicinity of the nose-tail axis.

[redacted] A configuration which reflects the low RCS features previously discussed is shown in Figure 20.

This assumes absorber treatment for much of the external surfaces and inlet/exhaust ducts. The levels of RCS are based upon measured RCS data for missile components which are similar to that being shown.

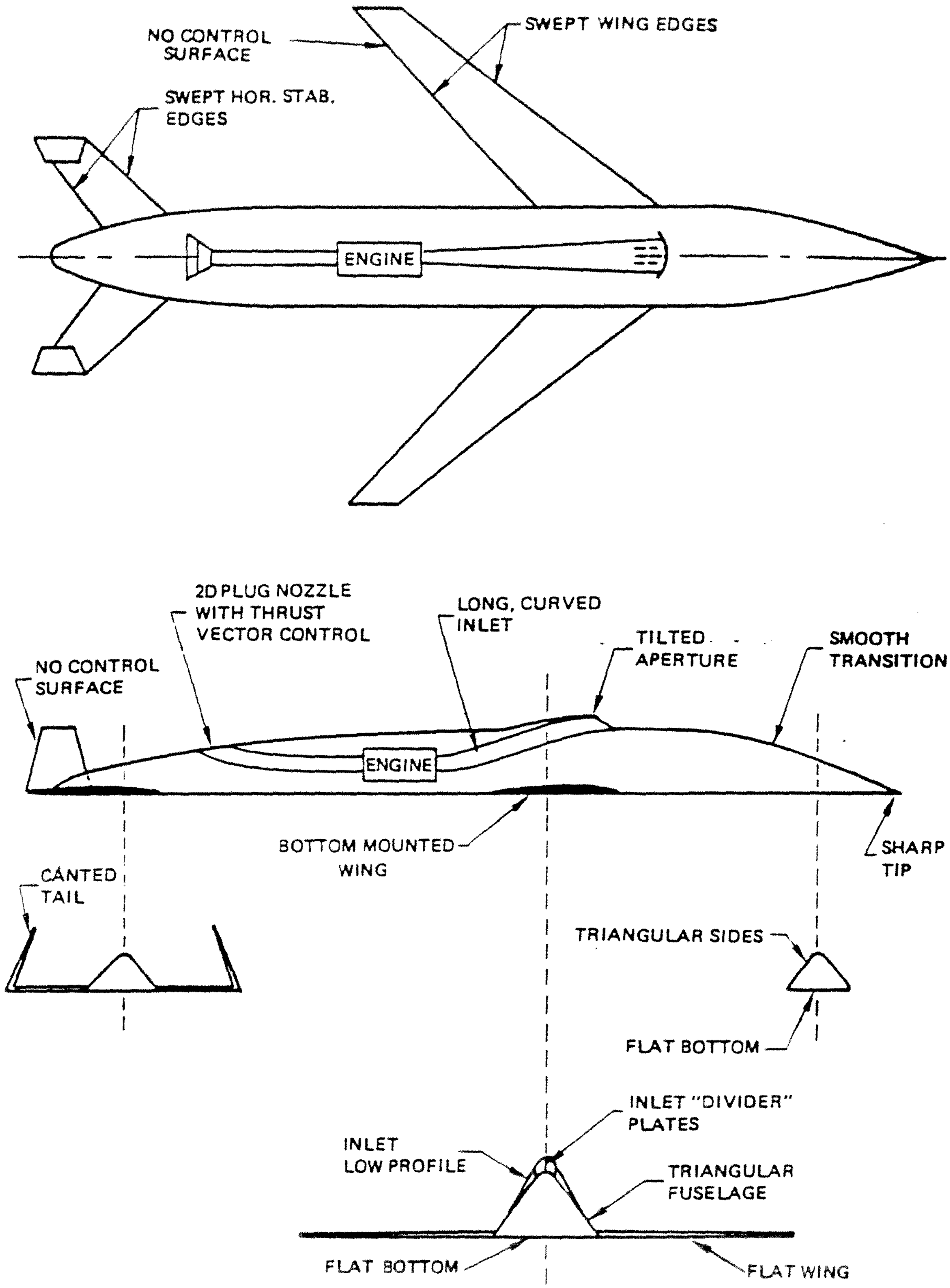


Figure 20: LOW RCS MISSILE DESIGN (U)

REFERENCES (U)

1. "Methods of Radar Cross Section Analysis", Edited by J. W. J. W. Crispin, Jr. and K. M. Siegel, Academic Press, New York and London, 1968

2. "Radar Cross Section Handbook", Volumes I and II, by Rusk, Barrick, Stuart, and Krichbaum; George Rusk, Editor. Plenum Press, New York and London, 1970

3. Northrup Corporation, Air Force Avionics Laboratory Document Numbers AFAL-TR-70-21, AFAL-TR-73-361, and AFAL-TR-74-112, April 1970 - September 1974

4. Ohio State University, Electro-Science Laboratory, Air Force Avionics Laboratory Contract No. F33615-67-C-1507, AFAL-TR-70-86, June 12, 1970, "Resonant Metallic Radome" (U), SECRET

5. The Boeing Company, Office of Naval Research Contract No. N00014-72-C-0303/NR 215-181, D180-15330-1, May, 1973, "Design of Aircraft Control Surfaces, Low Radar Cross Section" (U), SECRET

6. The Boeing Company, Office of Naval Research Contract No. N00014-71-C-0207/NR 215-184, D180-14192-1, January 1972, "Design of Naval Fighter-Attack Aircraft for Low Radar Cross Section" (U), SECRET

7. The Boeing Company, IR&D Study, 1970

8. The Boeing Company, Office of Naval Research Contract No. N00014-72-C-0303/NR 212-220, D180-17939-1, June 1974, "Design of Aircraft for Low Radar Cross Section - Broadside Sector" (U), SECRET

9. The Boeing Company, IR&D Study, 1973

10. The Boeing Company, IR&D Study, 1970

11. The Boeing Company, Contract AF 33(657)-15530 AGM-69A, D2AGM-12225-1, March 1966, "Detailed Analysis, Missile Radar Cross Section" (U), SECRET