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ASD-TR-78-23 ✓

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INNOVATIVE STRATEGIC AIRCRAFT DESIGN STUDY PHASE I (U)

LEVEL II

AC016293

Los Angeles Aircraft Divison
Rockwell International
Los Angeles International Airport
Los Angeles, California 90009

June 1978

Technical Report ASD-TR-78-23

Final Report

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Prepared for
DEPUTY FOR DEVELOPMENT PLANNING
AERONAUTICAL SYSTEMS DIVISION
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

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NOTICE

This technical report has been reviewed and is approved for publication.

Capt Milton R. Moores
ISADS Study Manager

Lt Col Paul C. Anderson
Director of Strategic Planning

S. A. Tremaine
Actg Deputy for Development Planning

INNOVATIVE STRATEGIC AIRCRAFT DESIGN STUDY PHASE I (U)

Los Angeles Aircraft Divison
Rockwell International
Los Angeles International Airport
Los Angeles, California 90009

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This study dealt with technologies and concepts for a post-1995 manned penetrating strategic bomber. Applicable technologies were assessed in areas of aerodynamics, propulsion, structures, controls, and stealth, and were found to offer up to 50-percent reductions in cost and weight over current technologies. Five aircraft concepts were sized to a "hi-lo-lo-hi" penetrating mission. Life cycle costs and master program schedules were prepared for each concept.

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SUMMARY

(U) The Innovative Strategic Aircraft Design Study (ISADS) was conducted to identify and assess advanced technologies offering favorable impacts on a post-1995 manned strategic penetrator, and to evaluate those technologies by integrating them into five strategic aircraft concepts:

1. Low-Cost Simplistic
2. Minimum Weight
3. Minimum Penetration Time
4. Low Observables
5. Laser Defended

(U) The technology areas investigated included aerodynamics, propulsion, structures, controls, and stealth. A 50-percent reduction in cost and weight was obtained for the ISADS concepts using 1995 technologies, which include composite primary structure, superplastic-formed/diffusion-bonded (SPF/DB) titanium nacelle structure, advanced supercritical airfoils, active and passive laminar flow control, advanced afterburning turbofans, and active controls.

(U) The five concepts were sized to an unrefueled 5,250-nautical-mile "high-low-low-high" strategic penetration mission. Takeoff weights of 300,000 to 550,000 pounds were obtained, as compared to over twice that for a comparable current technology baseline sized for the same mission. Flyaway costs were found to be about $35 million (1977 dollars), excluding technology development costs. Master program schedules showed RDT&E start dates around 1985 in order to obtain 1995 initial operational capability (IOC).

(U) The major lessons learned from ISADS are that substantial weight and cost savings (up to 50 percent) will be realized by technologies now under development, and that weight and cost of a follow-on manned penetrator will be very sensitive to assumptions made early in the design process as to mission range, speed, altitude, refueling capability, and subsystem requirements.

Section I

INTRODUCTION

PROGRAM OVERVIEW

(U) The Innovative Strategic Aircraft Design Study (ISADS) was sponsored by the Air Force Aeronautical Systems Division, Deputy for Development Planning (ASD/XRT). Its purpose was to identify alternate approaches to the preliminary design of advanced strategic aircraft through the application of innovative concepts and the most effective combinations of advanced technology. The findings of the study will be applied to establish guidelines for Air Force and industry technology advancement activities and to provide a system option for exercising in planned strategic mission analyses wherein the spectrum of penetration approaches will be considered.

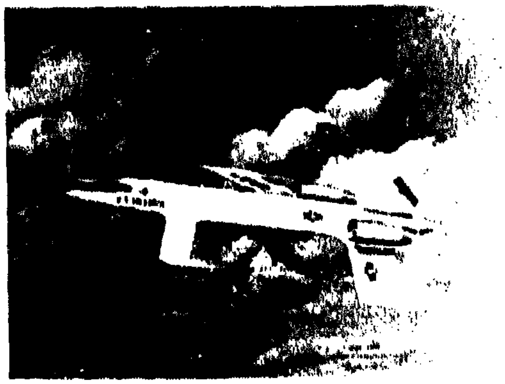
(U) Figure 1 summarizes the five baseline concepts developed to meet the ISADS 5,250-nautical-mile "high-low-low-high" penetrative mission. Weight and cost savings in excess of 50 percent compared to a current technology aircraft sized to meet the same mission are due to the application of 1995 advanced technologies identified in the first task of the ISADS study. These technologies include aerodynamic surface coatings, advanced supercritical and variable camber wings, composite primary structures, advanced afterburning turbofans, and active controls.

PERSPECTIVE

(U) Since the conclusion of World War II, America's defense posture has rested on the strategic nuclear deterrence philosophy. For almost 20 years, this has been manifested in the Triad concept, in which land, sea, and airborne nuclear forces complement each other's deterent effect and provide a measure of security against a sudden technological development which could neutralize one force. Due to the age of the existing systems, all three legs of the Triad are due for update. The MX missile program is to update the land leg, and the Trident submarine program is to update the sea leg. The airborne leg, the manned bomber, is the only leg which provides a reasoned controlled capability through the entire spectrum of conflict and is the only leg which has been verified in actual warfare as indicated below:

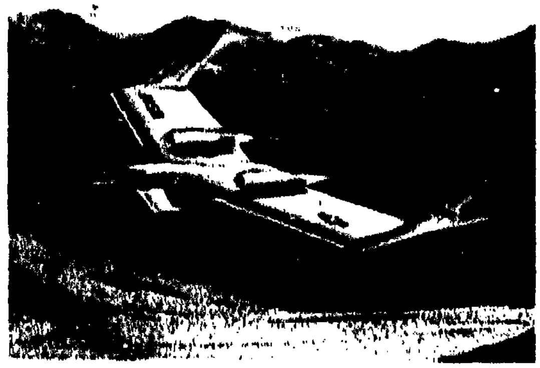
MANNED BOMBER ADVANTAGES

- Recallable
- Permits Show of Force



Low-Cost Simplistic

TOGW = 312,663
Length = 120 ft
Span = 121 ft
Flyaway cost = $34.4 M



Minimum Weight

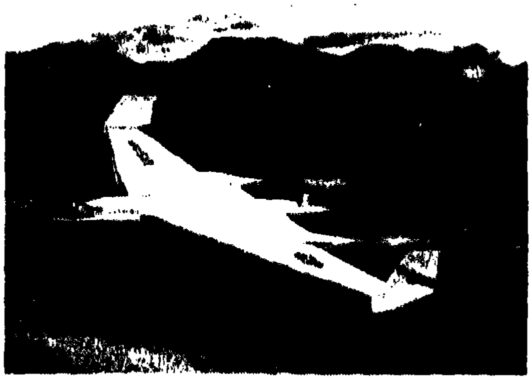
TOGW = 292,570 lb
Length = 48.1 ft
Span = 100 ft
Flyaway cost = $30.4 M

Minimum Penetration Time

TOGW = 551,880 lb
Length = 167.4 ft
Span = 128.6 ft
Flyaway cost = $52.9 M

Stealthy

TOGW = 302,396 lb
Length = 76.7 ft
Span = 81.1 ft
Flyaway cost = $31.8 M



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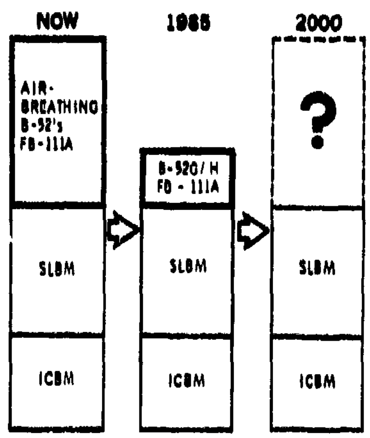
Laser Defense

TOGW = 340,808 lb
Length = 104 ft
Span = 115.8 ft
Flyaway cost = $40.3 M (+ laser cost)

(U) Figure 1. ISADS 1995 manned strategic penetrators.(U)

- Man at the Controls
- Survivable
- Flexible
- Reusable
- Only 'proven' element of the Triad (U)

(U) The importance of the manned bomber in the overall Triad concept is illustrated in Figure 2 which shows the relative number of warheads delivered on target by each leg of the Triad. Currently, the manned bomber provides just under half of the total. However, recent political actions have prevented the scheduled update of this leg of the Triad. By the year 2000, aircraft age will place the entire airborne leg of the Triad in doubt. It is to this unknown future that the ISADS study was addressed.



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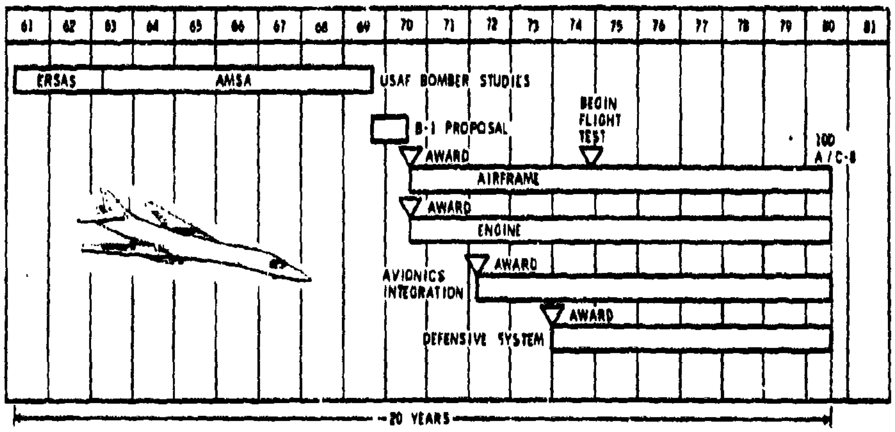
(U) Figure 2. Strategic warhead delivery requirements. (U)

(U) The Innovative Strategic Aircraft Design Study was conceived to examine advanced technology applications to conceptual strategic aircraft designed to meet postulated requirements of the post-1995 time period, and to conduct a technology assessment effort wherein the performance and cost/benefits expected through the use of advanced technology could be evaluated. The findings of this study will be applied to establish guidelines for Air Force and industry technology advancement activities and to provide a system option for exercising in planned strategic mission analyses wherein the spectrum of penetration approaches will be considered. The timeliness of this study is evident in Figure 3, showing the 20 years it would have taken to develop and deploy the B-1. Now is the time to start work for a 1995 Initial Operational Capability (IOC) manned strategic penetrator.



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(U) Figure 3. B-1 program history. (U)

ROCKWELL APPROACH

(U) The approach Rockwell selected to accomplish the ISADS study is a filtering or screening process (Figure 4). The initial inputs of requirements, mission, and payload data were enhanced with a selected list of technology candidates. These technology candidates were the result of an extensive technology identification and assessment effort dealing with 1995 technologies in the areas of aerodynamics, propulsion, structures, materials, and stealth. Advanced technologies offering improvements in cost, weight and performance were identified and analyzed as to probable availability date and system impact. From these technologies, a list of selected technologies was prepared and integrated into a number of aircraft concepts for each mission or system type. The configuration filtering process proceeded by accomplishing successively more detailed analyses on fewer and fewer configurations. These concepts were divided into the following catagories:

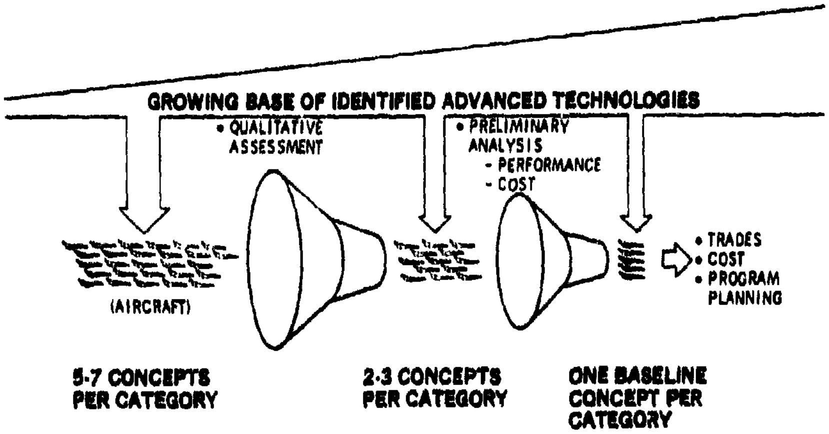
1. Low cost (simplistic airframe)

2. Best performance (minimum gross weight)

3. Best performance (minimum time at penetration altitude)

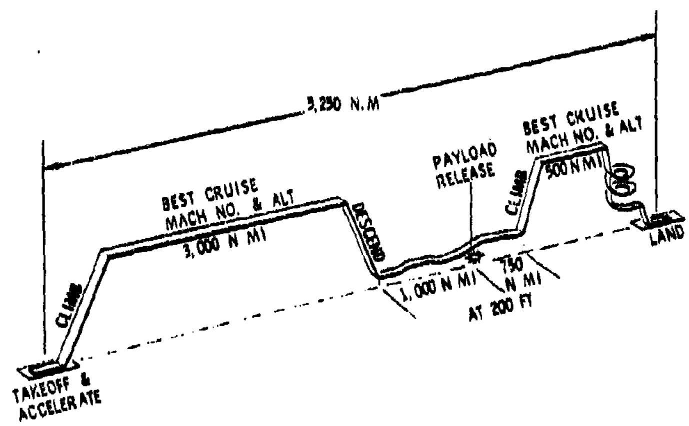
4. Low observables (stealth)

5. Laser weapon (defensive)

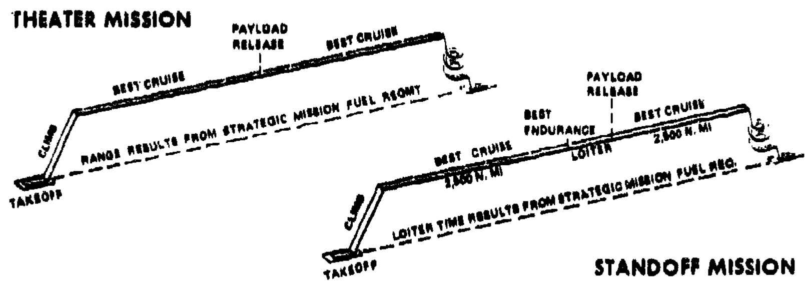


(U) Figure 4. Rockwell approach. (U)

(U) The results of the filtering process were a single baseline concept for each category, which was sized to a 5,250-nautical-mile-range high-low-low-high mission (Figure 5), with alternate theater and standoff missions (Figure 6). A 50,000-pound payload was assumed. Weight, performance, and cost results were prepared, along with program plans detailing source selection, full-scale development, production, IOC, and DSARC reviews. Trade studies evaluated the impact of selected configurational and technological trades.



(U) Figure 5. ISADS strategic mission. (U)



- RIDE QUALITY/FLIGHT CONTROL - AFFDL TR 73-135
- NUCLEAR HARDENING - 2 PSI PLUS GUST - 80 CAL/CM^2 ENVIRONMENT
- PAYLOAD - 50,000 LBS
  - 16 ADVANCED ALCM ON 2 ROTARY LAUNCHERS
  - ALTERNATE CONVENTIONAL STORES

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(U) Figure 6. Other program ground rules. (U)

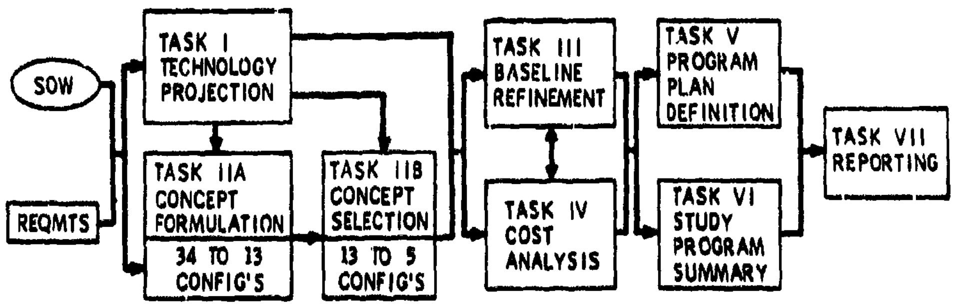
PROGRAM ORGANIZATION

(U) The ISADS was sponsored by the Air Force Aeronautical Systems Division, Deputy for development planning (ASD/XRT). The Air Force program manager was Capt. Milton R. Moores, USAF.

(U) The study was conducted by the Los Angeles Division of Rockwell International, with the Garrett AiResearch Manufacturing Company as subcontractor. Michael R. Robinson served as program manager, assisted by Daniel P. Raymer, deputy program manager. Individual tasks were directed by project managers from the appropriate functional area.

(U) The study was organized into seven tasks. These tasks and their primary components are presented in Figure 7. The task structure allowed maximum flexibility required for such a "forward-looking" program while providing the visibility to minitor progress and assure timely completion of each element of the program approach. The tasks are defined in the following paragraphs.

(U) These tasks are further detailed in Appendix A. Figure 8 summarizes the program schedule by task element.



(U) Figure 7. ISADS program flow chart. (U)

TASK I - TECHNOLOGY PROJECTION

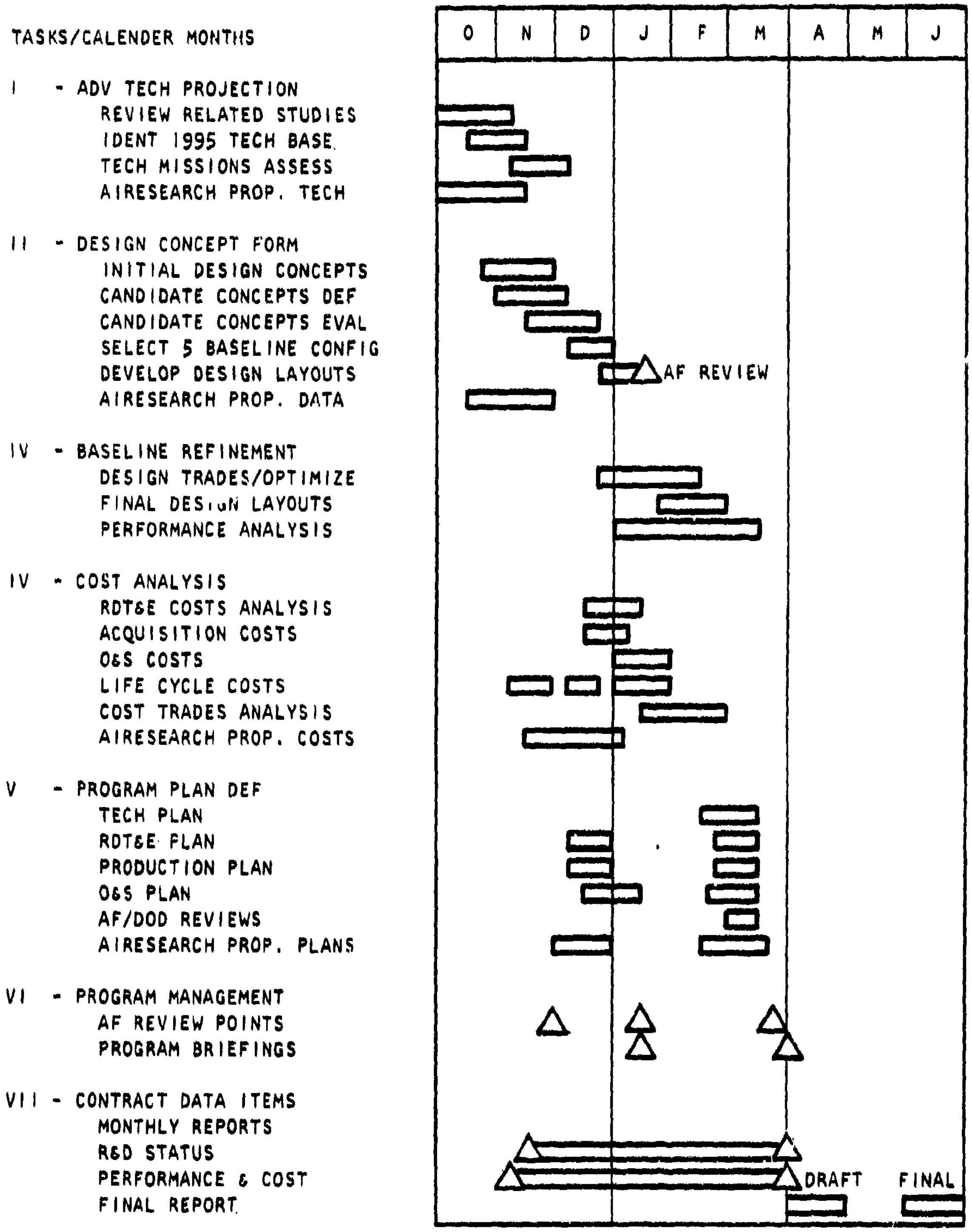
(U) In this task, Rockwell, with its subcontractor, Garrett AiResearch Manufacturing Company, projected the probable technologies suitable for implementation into a 1995 aircraft. Technologies were broken down into areas of aerodynamics, propulsion, flight controls, structures, and stealth, and assessed as to their cost, risk, and effectiveness for the year 1995.

TASK II - CONCEPT FORMULATION

(U) The advanced technologies identified in Task I were incorporated into 34 configuration sketches in the five categories previously mentioned. These con-concepts were subjected to a three-step filtering process to select one baseline for each category. These baselines were sized and drawn as detailed layouts.

TASK III - BASELINE REFINEMENT

(U) The five baselines were optimized and subjected to a series of trade studies by varying technologies and design features. Performance and weight was calculated for each trade.



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(U) Figure 8. Program schedule summary. (U)

TASK IV - COST ANALYSIS

(U) RDT&E, acquisition, operations and support, and life cycle costs were calculated for the five baselines. Cost sensitivities were prepared, and cost traces were conducted.

TASK V - PROGRAM PLANNING

(U) Development and production programs were prepared for each of the five baselines. Also, technology development plans were prepared.

TASK IV - PROGRAM MANAGEMENT

(U) Under this task all program management was budgeted.

TASK VII - CONTRACT DATA ITEMS

(U) Under this task adherence to Contract Data Items was tracked.

SUMMARY OF CONCLUSIONS

(U) The major conclusion of ISADS is that proper application of the technologies which will be available by the year 1995 can offer up to 50-percent reductions in total cost and weight for a given strategic mission when compared to the best of current technology designs. Individual savings will amount to 30-percent reduction due to advanced structures, 25-percent reduction due to advanced propulsions, and 40-percent reduction due to advanced aerodynamics and controls, as detailed within the body of the report.

(U) It was further shown that the major driver in determining the cost and weight of a follow-on strategic penetrator will be the initial assumptions as to mission, payload, avionics, and refueling. While perhaps not suprising, this conclusion reaffirms the importance of cost considerations in the earliest stages of system development. For this reason, the actual mission of any follow-on manned penetrating system should not be selected simply on the basis of technological feasibility or maximum probability of survival, but by detailed mission trade studies addressing cost, risk, effectiveness, and political/economic acceptability.

(U) Follow-on activities are recommended in several areas. Requirements studies should investigate enemy defense environment projects and evaluate standoff versus penetrating systems. Cost studies should evaluate the cost impact of payload versus force size, mission assumptions, and technology assumptions, and should determine as the bottom line what combination of mission and technology ground rule assumptions yields the highest target value kill for a given cost. Finally, additional concept studies should further refine the ISADS concepts, plus investigate several interesting combinations conceived, but not pursued, during the ISADS study. These include a multirole aircraft, a laser gunship, and a surface effect aircraft. (U)

Section II

TECHNOLOGY IDENTIFICATION

INTRODUCTION

(U) The progress of manned flight since its inception at the beginning of this century is attributable to advances in the state-of-the-art of the individual disciplines as they developed to meet the increasing challenges. The demand for added performance capability has advanced the design requirements for the next generation of vehicles, thereby stimulating the development of new technologies within the disciplines. Frequently, there are interactive effects wherein technology advances in one area permit a technology advance in another area not otherwise possible. The application of flight sciences has evolved to the level where advanced computers can solve complex problems, leading to more efficient designs not previously practicable. In its various diversified aerospace-related divisions, Rockwell is involved in the development and integration of advanced technologies in the areas of aerodynamics, propulsion, materials, structures, and stealth, where some significant advances are indicated by the 1995 time period. However, technology projections can only be made based on currently known and emerging concepts that have unrealized potential. Additional important improvements in technology will be provided by the unanticipated advances motivated by requirements and competition.

(U) Another development, although not a flight technology, will greatly influence the progress in all fields. The advent of new generation of large-capacity, high-speed, low-cost computers will enable the advancement of all flight sciences. Computational tools will enable the designer to advance his capabilities in an efficient manner and open the spectrum to additional applications.

(U) A combination of more sophisticated analytical and innovative design approaches has contributed to significant advances in the application and integration of materials and structures technologies. Projections indicate continuing improvements in lighter, less expensive, and aeroelastically responsive structures.

(U) Technologies evaluated during the study are listed in Table 1. Inspection of this list indicates that some technologies are currently being pursued in new airplane design evaluations, while others will require well-defined development programs for maturity by the 1995 time period. This section addresses the usefulness of some interesting advanced technology concepts applicable to strategic aircraft approaches required for this study.

(U) TABLE 1. CANDIDATE TECHNOLOGIES (U)

Propulsion	Aerodynamics
Variable-cycle engines	Laminar boundary layer
Nuclear engine cycle	Boundary layer control
Compressor improvement	Surface coatings
Combustor improvement	Advanced supercritical wing
Turbine improvement	Nonplanar wing
Fuel improvement	Advanced variable camber
Jet flaps	Relaxed static stability
	Coplanar wing
Materials	Blended wing-body
	Ground effect
Advanced composites	
Metallic materials	**Controls**
Metal matrix	
	Active controls/RSS
Structures	Integrated flight/fire/propulsion controls
Advanced structural mode control	Maneuver load control
Aeroelastic tailoring	Gust alleviation
Near-net diffusion control	
Superplastic forming/diffusion bonding	
Stealth	
Radar cross-section	
Infrared signature	
Noise signature	
Visual signature	

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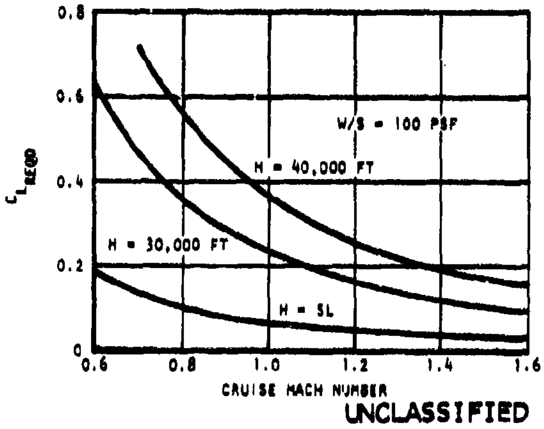
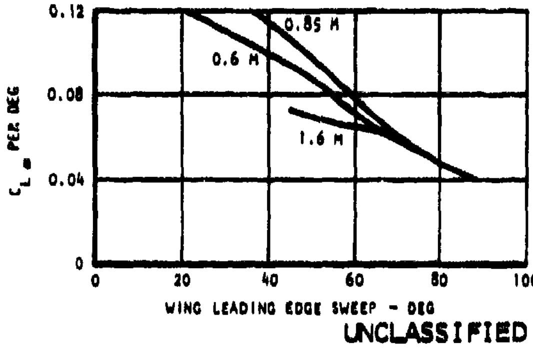
AERODYNAMIC CONCEPTS

(U) Aerodynamic design of strategic aircraft to perform a high-low-low-high type of mission presents two design points to be addressed. The requirements for efficient lift generation must be balanced between the relatively high cruise and the low-penetration design lifts. Current technology is embodied in the B-1 variable sweep aircraft design, which is ideally suited to minimize takeoff distance and maximize ride qualities, penetration speeds, and cruise efficiencies. This, of course, is not achieved without penalty in weight due to the variable sweep mechanism and, even with its aft-swept wing, a structural mode control system to enhance ride qualities. However, in the 1970-80 time frame, this manned aircraft system represents the most efficient approach to satisfying the high-low aerodynamic design points. Therefore, from this demonstrated base, several emerging aerodynamic technologies offer promise to be competitive in producing the most efficient future aircraft.

(U) Inspection of the lift requirements (Figure 9) for a low- and high-altitude cruise at a fixed wing loading reflects the mismatch of the wing design points. Clearly, the low-altitude penetrator will be optimized at a different wing size and geometry than the higher altitude penetrator. One approach to balancing these requirements is reflected in the reduction in lift curve slope of the variable swept wing (Figure 10). Another variable-geometry approach is the retractable wing, which will achieve the same purpose with an additional benefit of minimizing wetted area. Included in this approach could be variable camber aeroelastic tailoring, nonplanar wings, and possibly, jet flap propulsive lift enhancement to establish the most efficient lifting system.

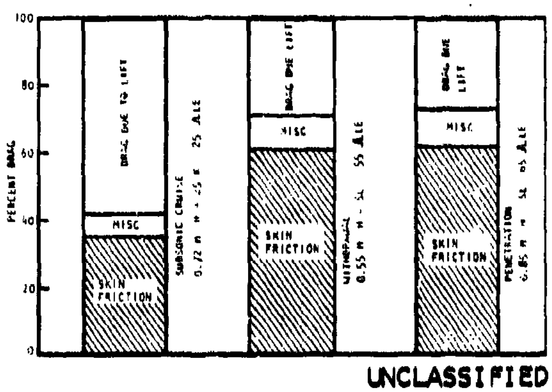


(U) Figure 9. Lift required. (U)

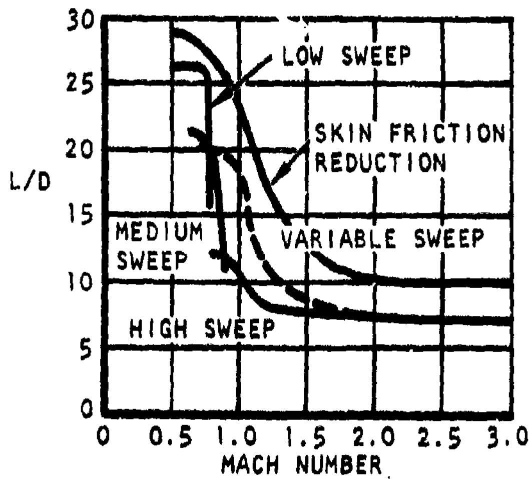


(U) Figure 10. Effect of wing sweep. (U)

(U) Aerodynamic efficiency is the guidepost. The selection of the most promising technologies will depend, to a great extent, on the mission ground rules and penetration speeds desired. However, current technology indicates that the largest share of the airplane resistance, and therefore the most fertile area for improvement, is in the viscous drag portion (Figure 11). Since skin friction represents 60 percent of the vehicle resistance in penetration, the laminar flow approaches and viscous drag reduction coatings currently being developed offer much promise. The laminar flow approach of smooth, short chord surfaces will blend with the minimum wetted area approach. The primary purpose of the designs will be to increase aerodynamic efficiency (Figures 12 and 13).



(U) Figure 11. Drag breakdown. (U)



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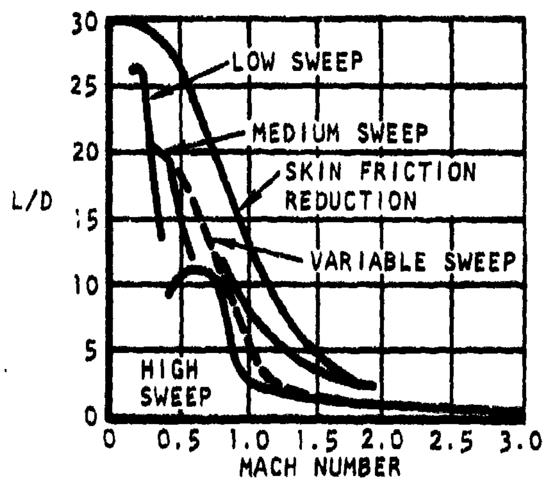
(U) Figure 12. Cruise altitude lift-to-drag ratios. (U)



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(U) Figure 13. Sea-level lift-to-drag ratios. (U)

(U) Recent advances in computational aerodynamics have made it possible to design lifting systems that produce low drag-due-to-lift in relation to currently accepted boundaries. The induced drag is a factor in the high-altitude cruise portion of the two design point missions (Figure 11). To reduce the drag levels below the current optimum span load of $1/\pi AR$ requires the nonplanar wing design or the jet flap. In both cases, the improvement is limited to increase in the effective aspect ratio. The jet flap has the possibility of improvement on the order of $(\pi AR+2C_J)$, and the nonplanar wing approaches on the order of 15-percent increase in effective aspect ratio. While these approaches are not to be neglected, they do not compare with the reduction potential of viscous drag.

(U) Technology advances will also be reflected in pressure or wave drag. Current blended wing-body or body shaping technology to minimize drag rise will be extended to provide lower wave drag levels such that low-altitude $M = 1.2$ to $M = 1.6$ penetration speeds are possible. Future computational aerodynamics are expected to permit rapid determination of the desired shapes in this area.

(U) Further advances in the understanding of the factors influencing more efficient lift production will also be reflected in the boundary layer control technology and the jet flap. Improved jet flap thrust recovery in conjunction with propulsive lift enhancement accentuates the opportunity for airframe propulsion integration, which, in the V/STOL area, has already produced significant progress. Considerable progress can also be made to reduce system drag through jet exhaust effects.

(U) Based on the preceding, some of the current technologies that are known to have unrealized potential in improving aerodynamic systems are discussed in the following paragraphs.

ADVANCED TRANSONIC WING DESIGN

(U) The experimental demonstration of a very low compressible drag rise through low supersonic speeds for a swept lifting wing-body configuration has been successfully accomplished by Bridgewater (Reference 1). The aspect-ratio 3.5 wing was swept 55 degrees and employed a 6-percent streamwise airfoil section. The twist and camber was defined to provide a "flattop" controlled subcritical flow with moderate upper surface adverse pressure gradients for a mach 1.2, $C_L = 0.15$ condition. The success of this design approach indicates avoidance of compressible pressure drag due to the formation of shockwaves and shock-induced boundary layer separation.

(U) The logical extension of this wing flow philosophy to higher free-stream mach numbers without recourse to increased wing sweep or thinner airfoil sections is based on the development and exploitation of controlled (shockless or weak shock) supercritical flow airfoils. The three-dimensional (3-D) upper urface wing target pressure distributions are still flattop but now would admit a local peak mach number of 1.2 or greater, followed by an isentropic or weak shock recompression.

(U) The supercritical design implementation requires the iterative use of a 3-D transonic relaxation solution to the small-disturbance theory or the full-potential equation of motion, as opposed to the linearized design philosophy widely used for subcritical flows. Close attention must be given to viscous effects if required for the mixed flow design as a result of the use of stronger pressure gradients. This can be accounted for by correcting the inviscid design wing contours for the effects of displacement thickness by undercutting.

(U) An alternate approach for moderate supersonic speeds is the application of a yawed wing swept behind the mach line to minimize the compressible drag rise. Either subcritical or mix flow wing flow technology may be employed and traded against wing thickness and sweep in the same sense as for a conventional wing. The use of the yawed wing has the further aerodynamic advantages of providing a low-sweep, high-aspect-ratio planform for takeoff and landing operations.

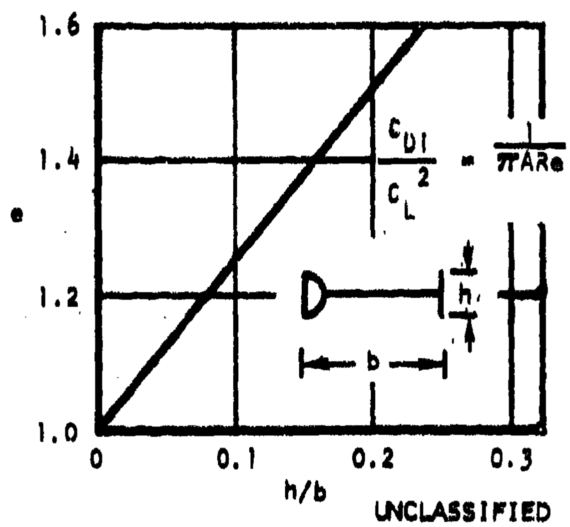
NONPLANAR WINGS

(U) The addition of winglets or other nonplanar devices has the potential to increase airplane lift curve slope, reduce induced drag, provide directional stability, and increase aerodynamic efficiency at the design condition. The aerodynamics of this effect are associated with the span loading of the wing. For the classic monoplane, the minimum induced drag is provided by a constant downwash across the span; this is given by an elliptical distribution of load. However, for nonplanar lifting configurations, the minimum induced drag is found to be associated with the vortex wake in the Trefftz plane on the wing.

In these cases, where a winglet, vortex diffuser, or end plate compose a nonplanar lifting configuration, the wing efficiencies are increased above the classical span loading solution. To achieve the potential increase in efficiency, the aircraft wing and winglet must be designed to carry the loading for minimum induced drag of a nonplanar lifting surface. (U)

(U) According to the theory of vortex drag optimization by optimizing twist and camber on the wing and winglet surfaces, span load distribution can be produced that will optimize vortex drag, provided other aerodynamic requirements are met. The theory provides the optimum span load for minimum vortex drag for wings which are nonplanar in the lateral direction and states that the vortex drag is a minimum when the trailing vortices produce a constant downwash in the Trefftz plane to solve for the spanwise distribution of lift or vortex strength. The vortex distribution which produces a constant downwash in the Trefftz plane is determined by solving for the spanwise distribution of vorticity along a lifting line of the same shape as the wing trailing edge, necessary to stop the flow, due to a constant upwash, from passing perpendicular to the lifting line.

(U) Improvement in theoretical drag-due-to-lift for a simple nonplanar wing end plate is shown in Figure 14. However, even though this technology is known, the full potential has never been achieved. Future applications in conjunction with advanced computers will increase the effectiveness of such surfaces. In this manner, the improvements in drag-due-to-lift will be reflected by increased effective wing aspect ratio.



(U) Figure 14. Theoretical nonplanar wing efficiency factors. (U)

VARIABLE CAMBER

(U) The variable camber wing concept employs leading and trailing edge geometry changes so that the wing camber can be varied for efficient operation over a wide variety of operations. The variable camber wing not only enables achievement of varying design lift coefficient, but also varying stability by planform extensions.

(U) There are to the present time basically two types of variable camber wing. In one type, leading and trailing edges simply deflect; in the other type, leading and trailing edges extend and deflect, thus providing an increase in wing area concurrently with variable camber. The result for both concepts is a higher usable $C_L max$ over a broad mach number range by preventing shocks and flow separation on the wing. Application of these devices can greatly improve loiter capability by reducing or eliminating flow separation at high angles of attack, thereby improving lift/drag (L/D) and reducing fuel flow required to maintain minimum-level flight speed.

(U) To develop high-lift coefficients at altitude and speeds where compressible effects are significant, the airfoil section will be designed to maintain supercritical flow on the upper surface without producing shock-induced separation. The wing must be designed to produce high-lift coefficients and buffet boundaries while maintaining low viscous and potential pressure drag.

(U) At the present time, on a conventional wing the variable camber is achieved by a mechanical system, and the wing twist by a combination of mechanical and aeroelastic tailoring techniques. However, in the future if a wing can be made of composite material, thereby eliminating the conventional wing box, both the wing twist and camber can be controlled by the aeroelastic tailoring technique or by an internal actuation system that forces the structure to deform to the desired shape without hinge line discontinuities. Systems of this type will permit maximum use of variable camber and provide an alternative to variable sweep.

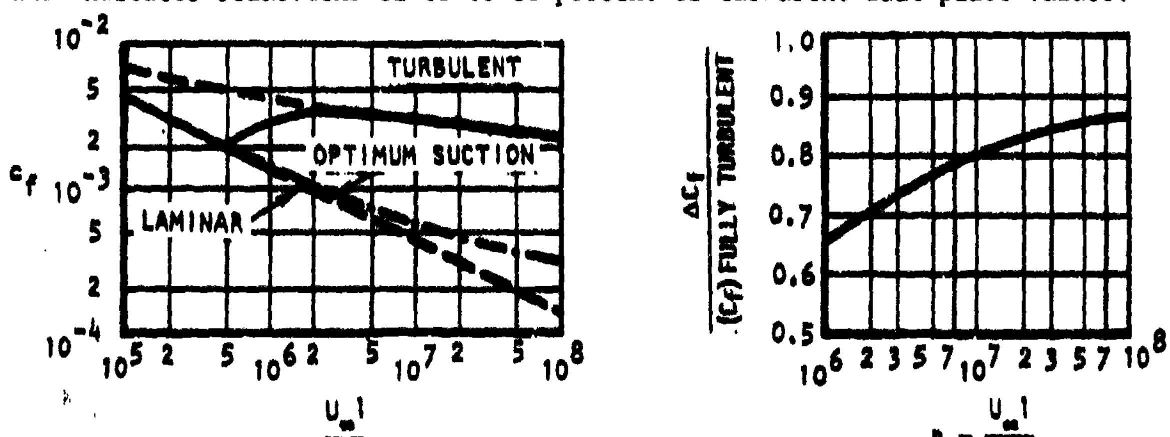
LAMINAR FLOW

(U) One of the greatest potential aerodynamic advancements which could produce significant performance benefit is the reduction of turbulent skin friction drag through elimination of roughness or delayed transition, or through use of active boundary layer control to maintain laminar flow. Experimental measurements indicate drag levels in excess of the flat-plate values shown as a result of form drag losses. This effect will be accentuated by future design trends employing thick wing sections with controlled supercritical flows and/or a relatively strong design rate of flow recompression.

(U) The use of favorable pressure gradients in combination with plastic coatings appears to be a promising approach for reducing skin friction drag by delaying transition at moderate Reynolds numbers (figure 22, ref. 22). The realization of such benefits on lifting wings must carefully consider the effect of boundary layer crossflow instability due to sweep and fuselage interference at the leading edge. At large Reynolds numbers, the benefit would primarily result from elimination of surface roughness on the first two-thirds of the wing and fuselage surface.

(U) As assessment of the potential for active boundary layer control through blowing and suction is more complex as a result of the energy requirements and the impact of the associated ducting on the aircraft structural weight. The ability to develop and maintain laminar flow on swept wings in flight at high Reynolds number using distributed suction was successfully demonstrated over 10 years ago by the X-21A program (ref. 23). However, an overall aircraft performance improvement incorporating such an approach has not been demonstrated to date.

(U) The potential benefit from unform suction on a flat plate is a function of the volume coefficient of suction $C_Q = Uo/U$. The condition $C_Q = 1.2 \times 10^{-4}$ corresponds to the requirement to just maintain wholly laminar flow. The relative saving in drag for this "optimum" suction is presented in Figure 15 and indicates reductions of 65 to 85 percent of turbulent flat-plate values.



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(U) Figure 15. Skin friction parameters. (U)

JET FLAPS

(U) The jet flap consists of the discharge of a high-velocity jet in the form of a thin full-span jet sheet from the wing trailing edge at an angle to the undisturbed stream. The resultant lift on the wing is considerably greater than the component of the reaction of the inclined jet, for the jet at the same time induces a circulation about the wing. Although not primarily a form of boundary layer control, the effect of the jet velocity does reduce the tendency to separate at high off-design lift coefficients and has been shown to minimize adverse pressure gradients, transonically delaying drag rise and improving drag-due-to-lift. Additionally, the gross thrust available is not seriously affected by moderate deflections of the jet. This phenomenon is called thrust recovery and has been demonstrated by experiment. Current technology is demonstrating initial applications of these concepts, and structural technology advancements are expected to provide greater jet flap enefits by the 1995 time period.(U)

WING BOUNDARY LAYER CONTROL

(U) In the design of lifting systems, the effect of viscosity is almost wholly adverse. Viscosity is responsible for friction drag and reductions in lift and often causes unsteadiness in the flow. The practical objectives of boundary layer control (BLC) are the reduction of drag and the suppression of large wakes, the increase in lift, and the improvement of stalling characteristics in general. These objectives are gained when the energy lost through viscosity is either minimized or recovered in an efficient manner. Thus, BLC technology is directed to prevent the separation of the boundary layer and to replace a turbulent boundary layer by a laminar one, or at least delay transition to a point as far downstream as possible.

(U) One type of boundary layer control is designed to minimize viscous drag. Transition to turbulent flow depends mainly on the roughness of the surface and the pressure gradients on it. Separation depends almost wholly on the pressure gradients. Therefore, the manufacture of very smooth unwrinkled surfaces and the surface shape is significant in the application of boundary layer control. The important feature of this type of control is that it does not involve the expenditure of additional power.

(U) Another boundary layer control approach involves the addition of energy to the boundary layer, thus delaying separation by the artificial transfer of energy. When auxiliary power is applied in boundary layer control, many opportunities arise. The low-energy air removal by suction or the injection of air to energize the boundary layer has been explored in detail. The objective is to increase efficiency by expending less power for boundary layer control than the equivalent thrust reduction achieved and weight penalty through its application. The combination of using advanced structural concepts, such as SPF/DB titanium or SPF aluminum, along with integral BLC slots and plenum chambers may show a BLC payoff of 10-15% TOGW reduction for either the high-altitude cruise application or the surface effect vehicle concept.

GROUND EFFECT

(U) An increased aerodynamic efficiency can be measured when lifting surfaces are operated within one wingspan of the surface of the earth, this improved efficiency increases with decreasing height. Because of the obvious influence of ground proximity during the takeoff and landing phases, it has been the subject of considerable investigation, but an adequate amount of reliable ground effects data does not appear in the literature. Both theoretical and experimental investigations indicate that ground proximity produces an increase in the lift-curve slope, a decrease in drag, and a reduction of noseup pitching moment for most aircraft planforms. The theoretical approaches analyzing ground effects employ an image-vortex theory to represent the ground plane. Away from the ground plane, the downwash of the two trailing vortices contributes to the wing drag-due-to-lift by rotating the force vector rearward. However, near the ground plane, the trailing vortices of the image vortex system have an upwash component which reduces the downward rotation of the flow direction caused by the wing trailing vortices, thus decreasing the wing drag-due-to-lift.

(U) The influence of the ground proximity is beneficial at low speed, and there is some evidence that end plates on wings further enhance these favorable effects. The velocity range potential of this characteristics is not known.

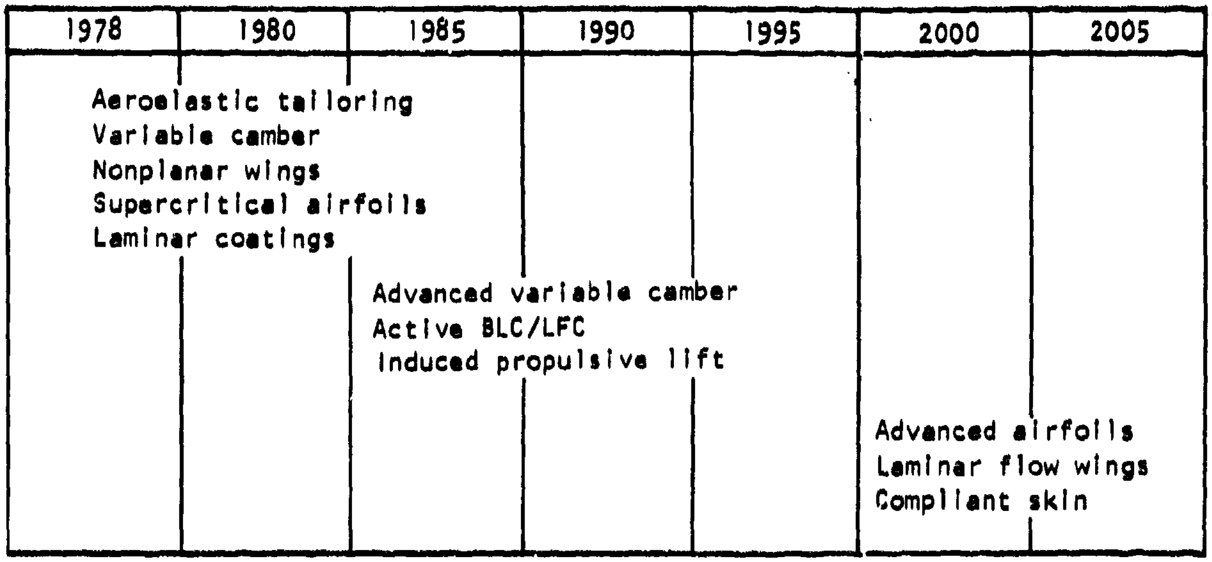
AEROELASTIC TAILORING

(U) Wing design using advanced composite structural material and employing unbalanced advanced composite ply layups to provide coupling between bending and torsional deflections is suited for aeroelastic tailoring to control wing twist and camber distributions. Through proper design, this combined structural-material-dynamics technology can result in significant aerodynamic improvement through control of wing twist and camber during flight. This design technique will also improve the control effectiveness of the wing trailing edge devices and fuselage bending.

(U) The principle involved in the structural twist control or the aeroelastic tailoring is that the wing can be made to deform under load such that the proper twist and camber are obtained at each spanwise station. Optimum wing twist and camber result in increased lift and lower drag at the design points, thereby altering the drag polar shape and improving the drag of the entire vehicle throughout the flight envelope. Improved air vehicle performance results in a reduced engine size, which, in turn, decreases the structural weight. These combined increments in system effectiveness, which were directly derived from judicious tailoring, will be translated into a significant cost-effective improvement of the weapon system.

(U) The optimally tailored design using 1995 technology of the composite critical component, by comparison to the less efficient quasiisotropic laminations, will ultimately afford an additional stiffness and rigidity improvement for a lighter weight, equal-strength composite structure that satisfies the aerodynamic requirements. With aeroelastic tailoring, the designer has more latitude to insure that aerodynamic requirements can be achieved within stringent weight and cost constraints.

(U) The projected availability dates of these aerodynamic technologies are summarized as Figure 16.



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(U) Figure 16. Aerodynamic technology projections.(U)

PROPULSION TECHNOLOGY ASSESSMENT

(U) Propulsion technology candidates were divided into five categories; i.e., inlets, engines, nozzles, controls, and fuels.

INLETS

(U) The assessment of inlet concepts and technology candidates is summarized in Table 2. Only modest improvements in inlet total pressure recovery are anticipated by 1995. Major improvements will be in the areas of reduced weight and drag, inlet/engine control integration, and reduced radar visibility. For design speeds of mach 1.6 or less, normal shock inlets and fixed two-dimensional (2-D) and semicone inlets provide pressure recovery as good or better than more complex variable inlets (usually used for higher design speeds) and are also lighter. Because the normal shock inlet is lightest, it was used for all aircraft concepts in this study. (U)

(U) TABLE 2. ISADS TECHNOLOGY ASSESSMENT - INLETS (U)

	Mission Segment								
Potential technology	T.O. and land	Climb and cruise	Dash	Weapon drop	Loiter	Cost	S/V	Maintenance	Comments
Variable capture area, variable incidence	L(recovery)	~0	L(drag)	0	~0	-(Complex)	~0	-(Complex)	
Radar absorbent material	0	0	0	0	0	~0	H(RCS)	0	
Forebody boundary layer bleed	0	0	-(BLC drag)	0	0	-(Complex)	M(RCS)	-(Complex)	
Fuselage/wing BL ingestion	-(Recovery)	?	?	0	?	-(Complex)	~0	-(Complex)	
"Bulb" engine hub with ram	-(Recovery)	-(Recovery)	-(Recovery, drag)	0	~0	-(SFC)	H(RCS)	~0	
Vanes with ram	-(Recovery)	-(Recovery)	-(Recovery)	0	-(Recovery)	-(Complex)	H(RCS)	-(Complex)	
Offset duct with ram	-(Recovery)	-(Recovery)	-(Recovery)	0	~0	~0	H(RCS)	~0	

Note:

H - High payoff
M - Medium payoff
L - Low payoff
0 - No payoff
- - Negative payoff
? - Unknown until further study

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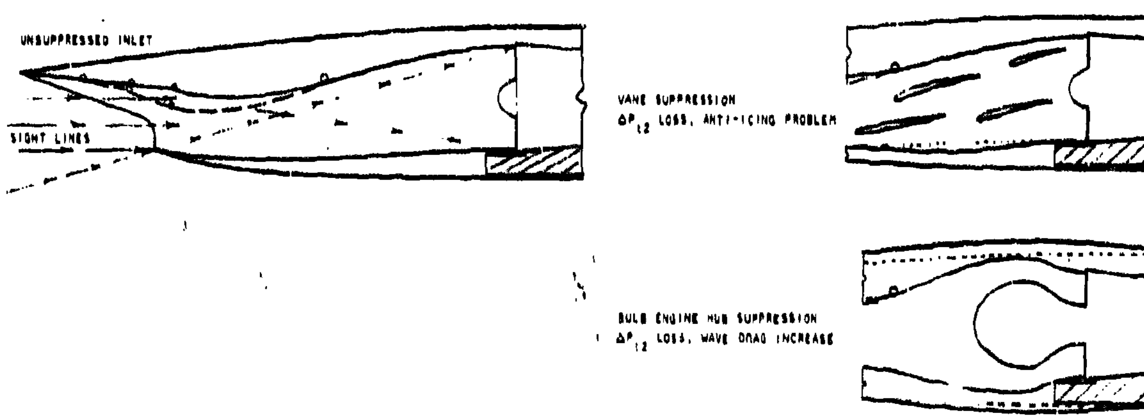
(U) Variable capture area and variable incidence inlets, such as are used on the F-15, provide better inlet/engine matching over wide variations in the flight regime than do fixed inlets, plus reduced drag and favorable pitching moments. This type of inlet was considered for the minimum penetration time design, but it was not used because of complexity, weight, and little performance advantage at mach 1.2.

(U) Location and inlet type can have significant impact on the radar cross section (RCS) of the aircraft. Thus, overwing locations were considered for lower hemisphere stealth designs. This location has an advantage relative to underwing inlets, in that the wing shields the inlet from low-level (ground-based) radar. A Rockwell RCS 1/4-scale model test of an ATS configuration showed that the overwing inlet is virtually invisible to lower level receivers (Reference 2). Additional benefits of overwing inlets include shielding from debris from the runway and more flexibility in attaching external stores. The primary disadvantages of overwing inlets are that (1) the inlet operates in an expansion flow field and thus requires a larger capture area, and (2) the local flow field may become highly distorted during maneuver, possibly causing engine stalls. Proper design can minimize these problems. (U)

(U) Addition of radar-absorbent material (RAM) to inlet internal surfaces reduces RCS with little or no weight and inlet performance penalties. Therefore, it was included in the stealth airplane. Eliminating direct line-of-sight to the engine face also reduces radar signature. One method of doing this is to use an offset inlet duct. This method, when combined with the use of RAM, provides highly effective means of reducing radar signature from the front of the aircraft. However, there is a modest loss in performance because the inlet pressure recovery is lower due to the turning.

(U) Other engine line-of-sight RCS suppression methods include the addition of vanes with RAM in the inlet and use of a "bulb" engine hub with RAM for a complete line-of-sight blockage. Use of vanes to block line-of-sight to the engine causes an inlet pressure loss and presents a severe anti-icing problem. The bulb engine hub will cause a modest inlet pressure loss (estimated to be less than 1 percent) and will increase drag because the nacelle cross-sectional area is increased. The bulb can be easily anti-iced with engine bleed air. Figure 17 illustrates these devices.



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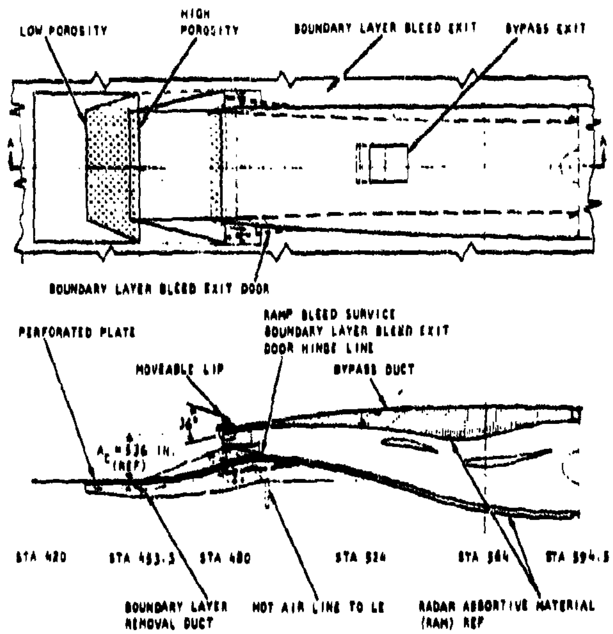
(U) Figure 17. Inlet RCS suppression methods. (U)

(U) Another source of radar signature is the inlet boundary layer diverter. The conventional boundary layer diverter may be replaced by a suction boundary layer control (BLC) system. The forebody boundary layer is bled through a perforated area forward of the ramp, into a plenum chamber, and exhausted through triangular exits on the side of the inlet. The suction surface has a high-porosity strip immediately forward of the ramp to prevent boundary layer/

shock interaction. The bleed airflow is controlled by triangular ramp doors which have the BLC bleed exit area on the sides of the inlet cowl. Rockwell has been investigating this concept in recent IR&D ATS studies. Estimated drags for the BLC system are equal to or less than the conventional boundary layer diverter. Figure 18 illustrates an upper inlet with this type of bleed system. (U)



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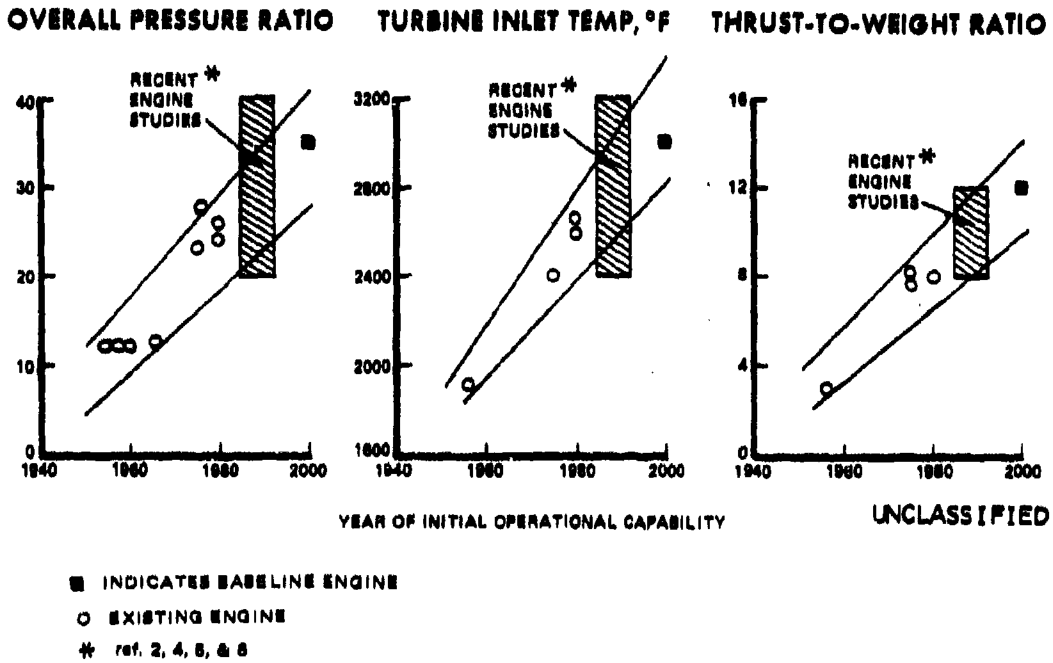
(U) Figure 18. Forebody boundary layer bleed. (U)

(U) One drag-reduction technique which NASA plans to study is boundary layer ingestion; that is, a propulsion system which uses fuselage and/or wing boundary layer air as its primary source of air. The advantages of this type of system are that (1) part of the ram drag of the propulsion air is accounted for in the aerodynamic drag, and (2) base drag is reduced by not discharging low-energy boundary layer air. However, this system requires more complex ducting with associated pressure losses. Previous studies have shown reduction in fuel consumption of from 5 to 10 percent, depending on the complexity of the system.

ENGINES

(U) Advances in engine component technology and engine cycles will improve propulsion system performance and weight (Figure 19). Engine technology assessment is summarized in Table 3. The following is a discussion of engine component performance levels and engine cycles which may be considered for the 1995 time period.



(U) Figure 19. Engine technology trends. (U)

(U) TABLE 3. ISADS TECHNOLOGY ASSESSMENT - ENGINES, NOZZLES, AND CONTROLS (U)

Potential technology	Mission segment: T.O. and land	Climb and cruise	Dash	Weapon drop	Loiter	Cost (procurement, LCC)	S/V	Maintenance	Comments
Current engine	0	0	0	0	0	0	0	0	Base engine
Advanced turbofan engine	L(fuel, eng, wt)	M(SFC)	L(SFC)	0	M(SFC)	+,M(SFC)	M (IR)	L	
Variable cycle engines									
VBCE	L(fuel, wt)	M(SFC)	L(SFC)	0	M(SFC)	+,M(SFC)	+(IR)	+(Complex)	
VABI	L(fuel wt)	M(SFC)	L(SFC, IR)	0	M(SFC)	+,M(SFC)	L(IR)	+(Complex)	
MMIPE	M(thrust, fuel wt)	M(SFC)	M(SFC for supersonic pen.)	0	M(SFC)	+,M(SFC)	L(IR for supersonic pen.)	+(Complex)	
Vari-flow rad comp	L(fuel wt)	M(SFC)	L(SFC, IR)	0	M(SFC)	+,M(SFC)	L(IR)	+(Complex)	
VGT turbojet	L(thrust)	≈0	L(SFC)	0	≈0	+,M(SFC)	L(IR for supersonic pen.)	(Complex)	
Nuclear engine	≈0	H(SFC)	H(SFC)	0	H(SFC)	?	L(IR), +(damage)	+(Complex)	Hi-risk, political, environmental
Turboprop	H(thrust, fue wt)	H(thrust, SFC)	L(SFC)	0	H(SFC)	L,H(SFC)	H(IR),+(RCS)	≈0	Limited to mach 0.8
RATO	H(thrust)	≈0	≈0	0	≈0	+,+	0	+(Complex)	Indirect savings if T.O. thrust sizing
Regen/inter cooled cycles	≈0	L(SFC)	≈0	0	L(SFC)	+, 0	L(IR)	+(Complex)	
Integrated controls FPPC	L(thrust, SFC, control surfaces)	L(thrust, SFC)	L(SFC	L(stability)	L(SFC)	0, M(SFC)	M(alternative opr modes)	M(self diag)	
Non-axisymmetric nozzles	L(thrust vec)	L(SFC)	L(SFC)	≈0	L(SFC)	+,L(SFC)	M(IR,RCS)	L	
Engine component improvement									
Compressor	L(thrust, wt)	L(SFC, wt)	L(SFC, wt)	0	L(SFC, wt)	L, L(SFC)	≈0	L(radial)	
Combustor	H(thrust, wt)	L(thrust)	≈0	0	0	M(engine size)	≈0	0	Combustor and turbine tech dev
Turbine (temp and cooling)	M(thrust, wt)	M(thrust, SFC)	L(SFC)	0	L(SFC)	M(engine size)L(SFC)	≈0	0	Must coincide
Augmentor	L(SFC, wt)	L(wt)	≈0	0	L(wt)	L,L(SFC)	≈0	0	Low risk

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Component Performance Levels

Compressors

(U) The major technology trends for fans and compressors are:

1. Higher loading at current or slightly increased efficiency (refer to Table 4 and see Figure 20)
2. Clearance control
3. Variable geometry

(U) The result of higher loading is to reduce the number of compression stages required, and minimize weight and cost.

(U) TABLE 4. COMPRESSION EFFICIENCIES (U)

	Typical Efficiencies (%)	
	Peak	100% Speed
Fan	89	86
Compressor	88	87

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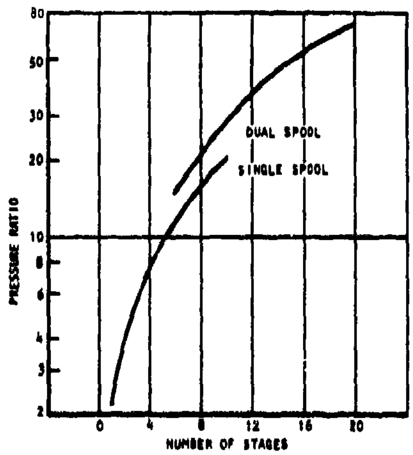

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(U) Figure 20. Compression stages. (U)

(U) Advanced three-dimensional (3-D) analysis methods and experimental techniques will play a major part in realizing the higher loadings at current or increased levels of efficiency. At the higher loading, more attention must be given to secondary flows, as well as end wall and boundary layer losses which can only be understood and characterized by fully 3-D analysis techniques. The fully 3-D analysis techniques are beginning to be used in the design of turbines, and will be extended to use in compressors.

(U) The advanced 3-D analysis methods need to be supported by advanced experimental techniques. Currently, the acquisition of experimental data is limited by the size and frequency response of the instrumentation. The laser doppler velocimeter (LDV) is one new method of instrumentation that promises to solve the problem without interference with the airflow. Velocity measurements can be made at virtually all locations of interest except in close proximity to walls, blades, etc. Further improvement of the techniques is required to reduce this limitation. The availability of measurements such as provided by the LDV is vital to correlate experimental results with the 3-D analysis methods.

(U) Variable cycle engines offer important benefits to strategic aircraft, particularly when the missions consist of a combination of supersonic and subsonic elements. Compressor and fan variable geometry is required to implement many variable cycle concepts. This variable geometry must not only provide increased surge margin as it is presently used but also provide the capability to alter the flow/pressure ratio/speed characteristic over a wide operating range.

(U) Another potential area of improvement is the use of centrifugal compressors as the final compressor stage of high pressure ratio cycles. Air Force and industry studies have shown that centrifugal compressors can offer advantages in reliability, maintainability, and cost at comparable performance when compared to all-axial compressors.

(U) The trend towards higher loading can result in higher compressor and fan tip speeds. Materials with properties adequate for these higher tip speeds need to be developed. Metal (boron aluminum and boron titanium) and organic matrix composites are candidates for high-speed [1,600 feet per second) fans but development work on their erosion and impact resistance is required. Composites may solve the tip speed problems in fan and low-pressure compressor stages but are limited in temperature capability. New high-strength titanium alloys can solve the temperature problem in later compressor stages but are limited in tip speed, and have experienced titanium fires. The solution may lie in a combination such as titanium aluminumide blades and a high-strength titanium alloy disk.

(U) Clearance control is an important area for all rotating components. The effect of running clearances becomes larger as higher pressure ratios and higher turbine temperatures reduce the size of the components. Three possible areas of improvement in clearance control are:

1. Active (variable cooling air)

2. Passive (abradables, hard blade tips)

3. Aerodynamic

(U) The aerodynamic control of tip clearance losses is an area where significant benefits could be achieved using the 3-D advanced analysis methods through control of blade tip loadings and use of slotted or groved shrouds.

Combustors

(U) The main areas of combustor technology advancement will be:

1. Higher combustor temperatures

2. Advanced materials/cooling schemes

3. Lower pattern factors

4. Reduced surface area

(U) In the 1990 to 2000 time period, combustor outlet temperatures will approach 3,200° F. These increased temperatures will decrease the cooling air available to cool the combustor liner and advancements in material properties, and the use of thermal barrier coatings will be required. Better cooling schemes will also be required to effectively use this available cooling air.

(U) Higher cycle temperatures will increase the amount of turbine vane cooling air required. As turbine vane cooling air is increased, it reduces the air available for cooling the combustor, and its discharge from the vane tends to decrease turbine efficiency. Reducing the combustor pattern factor decreases the maximum hot-spot gas temperature, and results in lower required cooling flows. Better understanding of the combustion process (mixing, turbulence, effect of geometry, fuel-nozzle location) will be required to decrease pattern factor, and can allow combustors to become smaller. Smaller combustors have beneficial effects on engine length and weight, and reduce cooling requirements because of the lower surface area.

Turbines

(U) The use of ceramics, particularly in engines for unmanned aircraft, will be demonstrated in the early 1980's (Figure 21). The extension of ceramics to manned engines is considered feasible for the time frame considered in this study. Turbine inlet temperatures for uncooled ceramics will be limited to approximately 2,400° F in the 1990's. However, cooled ceramic blades and vanes as well as supporting structures may allow operation of turbines in gas temperatures of 3,200° F with less cooling flow than currently used with much lower gas temperatures. (U)

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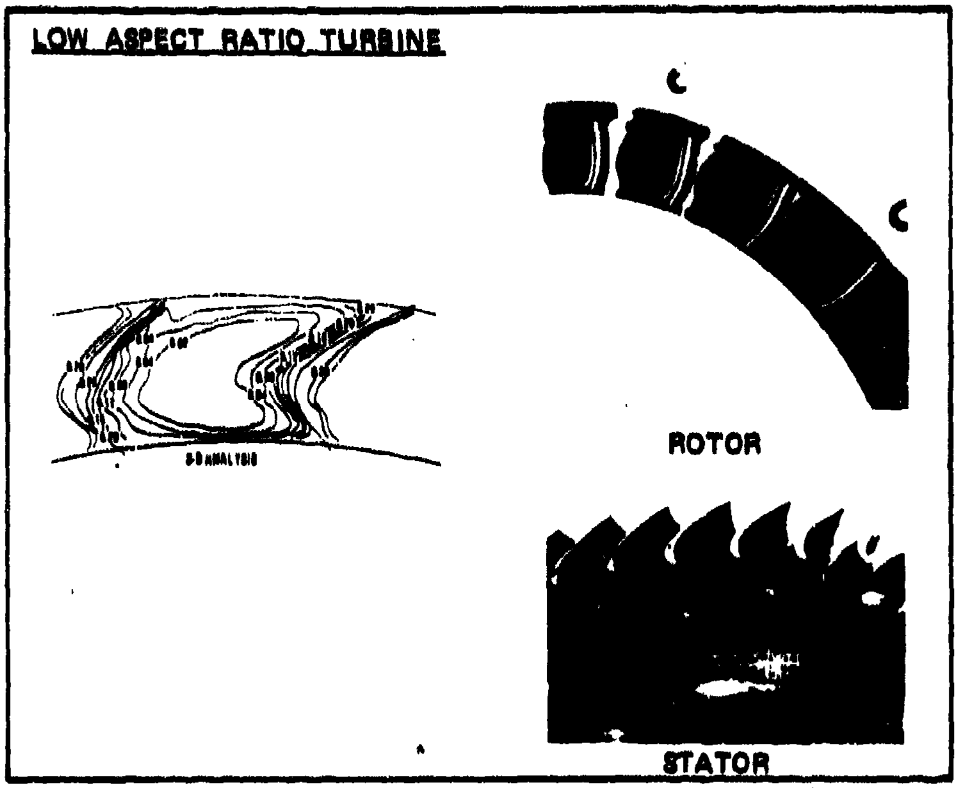
(U) Figure 21. Ceramic turbine blade. (U)

(U) Recent test results of the Air Force AFAPL low-aspect-ratio turbine (LART) program, being conducted by AiResearch, have established the future efficiency levels of high-work gas generator turbines for the 1980's (Figure 22). Tested efficiency of over 92 percent has established an industry level of aerodynamic efficiency for single-stage high-pressure turbines. The significant improvements achieved are attributed to the reduction of stator end wall losses by:

1. Optimizing the radial work distribution

2. Using 3-D viscous analytical techniques developed by AiResearch to select optimized end wall contours as well as stator lean and stack

(U) Another highly promising turbine technology area is the development of photoetched laminated turbine vanes and blades (Figure 23). Individual laminations are first photoetched from sheet metal. These are assembled, diffusion bonded, and trimmed to make individual cooled vanes. The advantage of the laminated construction is lower cost and the potential for highly effective cooling.



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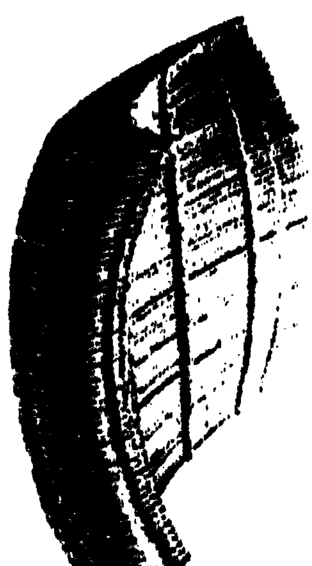
(U) Figure 22. Low-aspect ratio turbine. (U)



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(U) Figure 23. Photoetched laminated blade. (U)

(U) Maximum turbine cooling flow temperatures are currently around 1,100° F for supersonic cruise conditions; projected 1985 temperatures are 1,200° F. A further increase to about 1,300° F may be expected for 1995.

Augmenters

(U) Current technology augmenters have peak efficiencies of 96 to 97 percent and efficiencies near maximum augmentation (fuel-air ratios greater than 0.06) of less than 90 percent. Current augmenters tend to be nearly 4 feet long to achieve these efficiency levels. Swirl-can burners have recently been studied and tested which result in significantly higher efficiencies in shorter burner lengths (Reference 3). For example, peak combustion efficiencies of near 100 percent and efficiencies at high fuel-air ratios of 94 to 98 percent can be achieved in augmenters less than 2 feet long. The reduced length results in lighter weight and less required cooling flow (and, thus, higher maximum augmentation temperature and thrust).

Engines Cycles

(U) Engine cycles which were assessed include turbofans, variable-cycle engines, Rockwell's Multiple Mode Integrated Propulsion System (MMIPS), turboprops, regenerative and intercooled cycles, constant-volume combustion cycle, compound cycle, and rocket-assisted takeoff (RATO).

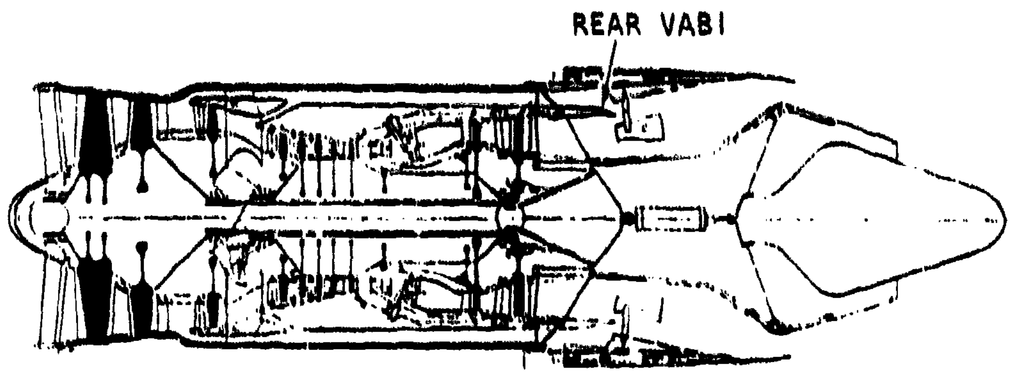
Turbofans

(U) Conventional mixed-flow turbofan engines provide low fuel consumption for subsonic cruise and low exhaust gas temperatures for low IR signature. A current engine may provide reduced cost by eliminating development cost.

(U) Current technology bomber engines have thrust-to-weight ratios of from 7 to 8. Military engines currently being studied with technology availability dates in the early 1980's have thrust-to-weight ratios approaching 11 for conventional cycles. This advance, relative to current engines, is being achieved through improved materials, higher specific thrust, higher stage loadings (fewer stages), and shorter augmenters. Continued improvement in materials through the late 1990's will improve thrust-to-weight ratio still further. Improved turbine materials and improved component performance levels will also increase specific thrust. Thus, thrust-to-weight ratios may be expected to be greater than 12 in the late 1990's. Variable-cycle engines and engines designed for high-speed, low-level flight would be expected to have somewhat lower thrust-to-weight ratios, depending on the particular design.

Variable-Cycle Engines (VCE)

(U) Variable-geometry turbine turbojets are currently being studied for application to ATS in the 1985 time period (Figure 24). Studies at Rockwell indicate that this cycle is very competitive in total system cost and performance with low bypass ratio, fixed-cycle turbofans, and variable-cycle turbofans in the ATF. However, for subsonic-only aircraft, turbofans will provide lower SFC.



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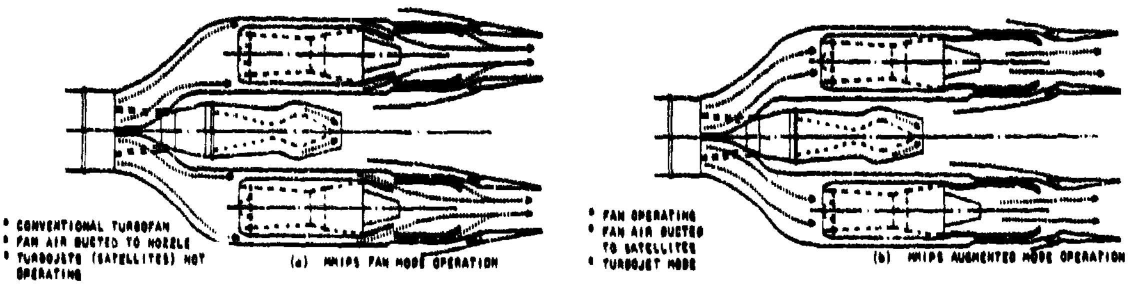
(U) Figure 24. Variable cycle engine. (U)

(U) One example of the advanced engines being studied at AiResearch and which could have application in this study is a unique VCE concept. It takes advantage of a characteristic of the centrifugal compressor, which allows compressor flow to be modulated without decreasing pressure ratio. Variable-geometry components include the variable-diffuser centrifugal compressor, variable-nozzle high- and low-pressure turbines, and the variable exhaust nozzle. Use of this engine in a high-performance fighter resulted in an 8-percent decrease in takeoff gross weight and a 22-percent decrease in fuel required when compared to conventional, advanced technology augmented turbofan.

(U) VCE's such as the General Electric variable area bypass injector (VABI) and the Pratt & Whitney Aircraft variable stream control engine (VSCE) have been considered for ATS and AST. Both cycles provide reduced SFC for multimission aircraft by maintaining airflow at the intermediate power level down to approximately 50 percent of intermediate net thrust. This also reduces inlet spillage and nozzle/afterbody drags. The VSCE has bypass and turbine streams separated, and thus will have high IR signature; also, it cannot be easily adapted to a 2-D nozzle.

(U) Multimission integrated propulsion system (MMIPS) has been investigated in several aircraft studies (Figure 25). These studies indicated that MMIPS is most promising in aircraft that have significant performance requirements at two or more significantly different flight conditions. Thus, MMIPS was considered for the minimum penetration time vehicle.



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(U) Figure 25. MMIPS concept and operation. (U)

Turboprops

(U) Recent engine manufacturers studies (References 4, 5, and 6) show that advanced turboprop engines have significant performance advantages up to mach 0.8 relative to advanced turbofans. However, propellers provide high radar signature return, even when composite materials are used. Thus, turboprops were not considered further.

Rocket-Assisted Takeoff (RATO)

(U) RATO can be considered when penalties might otherwise be incurred by the necessity of sizing the engines to meet a takeoff requirement. Other factors to be considered include a logistics problem and the structural weight penalty for mounting. Engine cycles were defined for each aircraft design which did not require RATO.

Regenerative and Intercooling Cycles

(U) Three concepts were considered:

1. Regenerative: The high-pressure compressor discharge air is ducted through a heat exchanger in the turbine discharge gas to preheat the

air prior to burning. This reduces specific fuel consumption. An additional advantage of this cycle is reduced IR signature due to lower exhaust gas temperature. Previous studies (References 4, 5, and 6) show that the performance gains tend to be offset by heat exchanger weight and pressure losses. Therefore, this concept was not recommended.

2. Intercooling: Cooling between compressor stages (for example, using liquid hydrogen as a heat sink) reduces the amount of work done to reach a given pressure. A study by Garrett/AiResearch indicates that performance may be improved slightly relative to a nonintercooled turbofan system. Here again, performance gains tend to be offset by weight and pressure losses; therefore, the concept was not recommended.

3. Turbine Cooling Flow Cooling: Cooling of turbine cooling flow (using fuel as a heat sink) results in lower amounts of cooling flow required and, thus, higher specific thrust. Because the cooling flow required for the engines of this study was so small, it was felt that there would be little or no payoff for this concept. (U)

NOZZLES

(U) Two nozzle types were considered: conventional axisymmetric and asymmetric (2-D). Nozzle concept and technology assessment is summarized in Table 3. Axisymmetric, convergent-divergent, independent variable exit area nozzles provide peak internal performance for all operating conditions. However, 2-D nozzles offer potential benefits in several areas. Significant benefits to the aircraft maneuver capability and takeoff/landing distance have recently been identified with in-flight thrust vectoring, thrust reversing, and supercirculation lift (propulsive lift enhancement). These benefits can improve maneuver performance for aircraft having given control surfaces sizes, or can result in smaller control surfaces with an attendant reduction in aircraft weight and drag for the same maneuver performance. These features are mechanically more easily applied to a 2-D nozzle than to their axisymmetric counterparts. Analytical studies have shown improved supercirculation lift for high-aspect-ratio (width/height) 2-D nozzle designs compared to the restricted circular shape of axisymmetric nozzles. In addition, drag for multiple-engine installations may be less because of cleaner aircraft lines.

(U) Finally, aircraft survivability/vulnerability is improved by the infrared radiation/radar cross-section (IR/RCS) signature suppression inherent in high-aspect-ratio 2-D nozzles. The exhaust plume diffusion rate is greatly increased with nozzle aspect ratio, and aft view RCS may be reduced with wedge or single-expansion-ramp nozzles by shielding the engine turbine.

PROPULSION CONTROLS

(U) The complexity of advanced aircraft and the required capability for multimission mode in-flight variation of the flying qualities to achieve a specific mission task dictate the use of advanced control concepts. Such a concept is the digital, fly-by-wire, flight/fire/propulsion integrated control system. Through a trim drag reduction, the incorporation of an integrated control system provides significant fuel savings in the penetration leg and the related increase in engine life. The concept permits steady-state performance to be optimized without regard to conventional stability margins required for transients; the transients may be sensed and stability margins may be increased for the duration of the transient. Assessment of this control concept is summarized in Table 3.

(U) The integrated fire/flight/propulsion control system concept was included in the propulsion system performance analysis.

FUELS

(U) Assessment of alternate fuels is summarized in Table 5. Solid fuels, slurries, liquid fuels, and nuclear power are discussed.

(U) TABLE 5. TECHNOLOGY ASSESSMENT - FUELS (U)

Alternate fuel	Specific gravity	Heating value, Btu/lb	Mission segment: T.O. and land	Mission segment: Climb and cruise	Mission segment: Dash	Mission segment: Weapon drop	Mission segment: Loiter	Cost	S/V	Maintenance	Comments
Acetylene	0.621	20,700	+(fuel wt)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	-(Increased vol)	-(Storage)	
Aluminum	2.702	13,300	-(low vol, low hv)	-	-	0	-	-(Expensive)	-(IR)	-(Abrasive)	
Ammonia	.609	8,000	-(fuel wt)	-(SFC)	-(SFC)	0	-(SFC)	-(Expensive	-(Increased vol)	+0	
Beryllium	1.85	28,100	+(fuel wt)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	-(IR)	-(Abrasive)	
Boron	2.3	25,100	+(fuel wt)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	-(Increased vol)	-(Exhaust deposits)	
Carbon	2.25	14,100	-(low vol, low hv)	-	-	0	?	-(Expensive)	-(IR)	-(Abrasive)	
Diborane	.44*	31,400	+(fuel wt)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	0	-(Exhaust deposits)	Toxic
Ethanol	.793	12,800	-(Hi vol, low hv)	-(SFC)	-(SFC)	0	-(SFC)	-(Expensive)	-(Increased vol)	+0	
Gasoline	.678	18,800	-(Hi vol)	+0	+0	0	+0	+0	+0	+0	
Hydrazine	1.0	7,200	-(fuel wt)	-(SFC)	-(SFC)	0	-(SFC)	-(Expensive)	-(Increased vol)	+0	
Hydrogen, liquid	.070	51,600	+(fuel wt)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	-(Hi vol, low IR)	-(Complex)	Storage, availability
Hydrogen, metallic	≈.7	51,600	+(low vol, hi hv)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	+(low vol, low IR)	?	Very hi risk
Hydrogen, slush	.081	51,600	+(fuel wt)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	-(Hi vol, low IR)	-(Complex)	Storage, availability
Kerosene	.82	18,300	0	0	0	0	0	0	0	0	Base fuel
Lithium	.534	18,100	-(Hi vol)	+0	+0	0	+0	-(Expensive)	-(Increased vol)	-(Abrasive)	
Lithium hydride	.82	17,400	+0	+0	+0	0	+0	-(Expensive)	?	?	
Magnesium	1.74	10,800	-(fuel wt)	-(SFC)	-(SFC)	0	-(SFC)	-(Expensive)	-(IR)	-(Abrasive)	
Methane, liquid	.42	21,100	-(Hi vol)	+(SFC)	+(SFC)	0	+(SFC)	+0	-(Increased vol)	-(Complex)	Storage, availability
Methanol	.79	4,600	-(fuel wt)	-(SFC)	-(SFC)	0	-(SFC)	+0	-(Increased vol)	+0	
Monomethylamine	.881	13,500	-(fuel wt)	-(SFC)	-(SFC)	0	-(SFC)	-(Expensive)	-(Increased vol)	?	
Pentaborane	.61	29,100	+(fuel wt)	+(SFC)	+(SFC)	0	+(SFC)	-(Expensive)	+0	-(Exhaust dep)	Toxic, spontaneous ignition
Propane	.58	19,900	-(Hi vol)	+0	+0	0	+0	+0	+0	-(Complex)	Storage, availability
Shelldyne H	1.09	17,600	+0	-(SFC)	-(SFC)	0	-(SFC)	+0	+(reduced vol)	+0	
Silicone	2.4	13,200	-(fuel wt)	-(SFC)	-(SFC)	0	-(SFC)	?	-(IR)	-(Abrasive)	
Syncrude	≈.8	≈18,000	0	0	0	0	0	+0	0	0	
Titanium	4.5	8,200	-(fuel wt)	-(SFC)	-(SFC)	0	-(SFC)	-(Expensive)	-(IR)	-(Abrasive)	

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Solid Fuels (Not Recommended)

(U) Some materials could be used in a dry powdered form as a fuel. These include aluminum, beryllium, boron, cirbon, lithium, lithium hydride, magnesium, silicone, and titanium. These materials tend to be expensive. In addition, incomplete combustion could result in rapid wear of engine parts downstream of the combustor and in increased IR signature.

(U) One new concept is that of metallic hydrogen. The metallic form would have a density approximately 10 times that of the liquid; thus, aircraft volume could be reduced dramatically.

(U) The NASA Lewis Research Center has given grants to Cornell University and to the University of Maryland to build presses designed to achieve the pressures required to make metallic hydrogen. These would start with gaseous hydrogen at atmospheric pressure. NASA Lewis is also designing a press, but it will start with liquid hydrogen. This press is to be completed late in 1978.

(U) The pressures required to achieve metallic hydrogen are estimated to be from 1 to 3 megabars (15 to 45 million psia). Whether it will be stable is not known. Thus, it was not recommended for consideration in this study.

Slurries (Not Recommended)

(U) The suspension of powders, such as those described in the preceding, in liquid fuels would result in the same problems as the solid fuels. In addition, storage of slurries may be a problem due to the settling out of the solid.

Liquids

Acetylene (Not Recommended)

(U) Acetylene would appear to provide a good alternate fuel based on fuel heating value. However, it is more expensive than either JP or synthetic JP, it would increase radar cross section because of the larger volume required, and it would result in additional ground handling requirements because of its low boiling point (-119° F).

Ammonia (Not Recommended)

(U) The very low fuel heating value of ammonia would result in very high fuel weight and volume. Storage of ammonia would create additional ground handling requirements because of its low boiling point (-28° F).

Diborane (Not Recommended)

(U) The heating value of diborane is attractive but its products of combustion include boron oxide (which could deposit on engine parts) and boric acid (corrosive). In addition, diborane is toxic.

Ethanol (Not Recommended)

(U) Ethanol has a low heating value, and it would result in increased aircraft volume (increased RCS).

Gasoline, Kerosene, and Syncrude Fuels (Recommended for All Vehicle Concepts)

(U) These fuels have very similar characteristics, and synthetic gasoline and erosene will probably be produced in quantity from oil shale, tar sands, and coal by the year 2000. The use of syncrude fuels as a replacement for the dwindling supply of petroleum-based fuels has several advantages relative to other fuels. Syncrudes, while more expensive than petroleum-based fuels today, will probably be the cheapest replacement fuel. These fuels will require no new storage or handling facilities. Use of syncrudes will mean minimum changes to existing aircraft. Dual fuel facilities will not be required. Fuel should be available at all existing airfields, as opposed to selected fields for a new fuel.

Hydrogen (Recommended for Investigation)

(U) In previous studies of low-density aircraft, hydrogen has resulted in lower takeoff gross weight than JP fuel. Thus, hydrogen was considered for the ISADS concepts. Hydrogen slush has advantages in that it is approximately 15-percent denser than the liquid, and there is less boiloff. However, the slush is also considerably more expensive to prepare. Another advantage of hydrogen is that IR signature is reduced.

(U) Cryogenic hydrogen has the obvious problems of storage (boiling point is -423° F), world-wide supply, safety, and portability. It has a very low volumetric heating value, is expensive, and is energy intensive, whether produced from electrolysis of water or derived from coal gasification (currently the least expensive means of production). Response time may be affected if fuel tanks have to be filled or topped off. Additionally, public fear of hydrogen may be difficult to overcome.

Methane (Not Recommended)

(U) Liquid methane also has problems of storage (boiling point is -259° F), supply, safety, portability, low volumetric heating value, and response time. Its volumetric heating value is higher than that of hydrogen, but its heating value per unit weight is poorer.

Methanol (Not Recommended)

(U) The primary disadvantage of methanol is its low heating value.

Monomethylamine (Not Recommended)

(U) Monomethylamine has a low heating value, and it is more expensive than ammonia or methane because both are used in its manufacture.

Pentaborane (Not Recommended)

(U) Pentaborane has disadvantages similar to those of diborane (production of boron oxide and boric acid, toxicity) and, in addition, it ignites spontaneously in air.

Propane (Not Recommended)

(U) Propane has a slightly higher heating value than kerosene but considerably lower density. Its low boiling point (-44° F) would require special handling It is also more expensive to produce than synthetic kerosene.

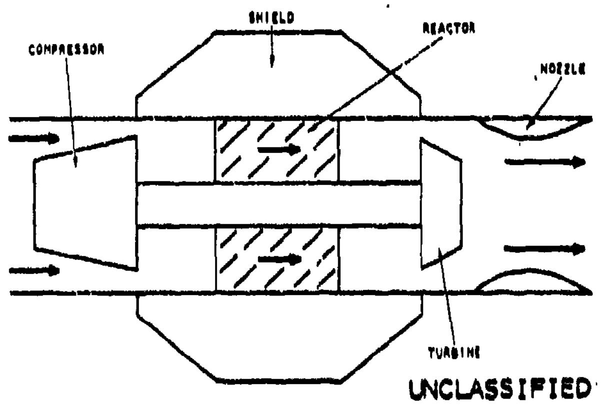
Shelldyne H (Recommended for Minimum-Weight Concept)

(U) Shelldyne has slightly lower heating value than kerosene, but it is much denser. For airplanes which have a fuel volume problem, Shelldyne may be used to advantage. This could aid in reducing volume and structure of the minimum-weight concept. Currently, it is considerably more expensive than JP because of a low production rate. With a high production rate, it might become competitive with JP.

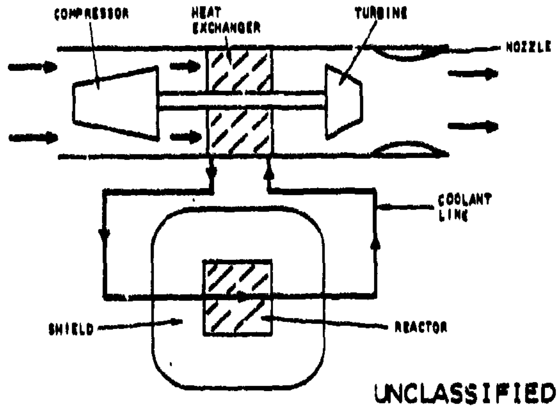
Nuclear Power (Recommended for Stealth Concept)

(U) Nuclear reactors may be used as a source of heat for aircraft turbine engines. Nuclear reactors have an almost unlimited energy source; therefore, they can perform long-endurance and long-range missions.

(U) Two nuclear heating methods were considered: direct and indirect. In the direct cycle, compressor discharge air is ducted through the nuclear reactor and thence to the turbine and nozzle (Figure 26). The indirect cycle uses a coolant to remove heat from the reactor and transport it to a heat exchanger in the compressor discharge airflow stream (Figure 27). The direct cycle is simpler, but the indirect cycle has a greater air intake capability. Several engines can be associated with one reactor; this arrangement yields minimum weight. However, a configuration which has one reactor per engine is simpler. In a direct cycle, the engines are generally adjacent to the reactor shield. The indirect cycle permits more freedom in locating the engines. Because of the excessive weight of shielding each reactor in a direct cycle, only the indirect cycle was considered in this study.



(U) Figure 26. Direct-cycle nuclear turbojet. (U)



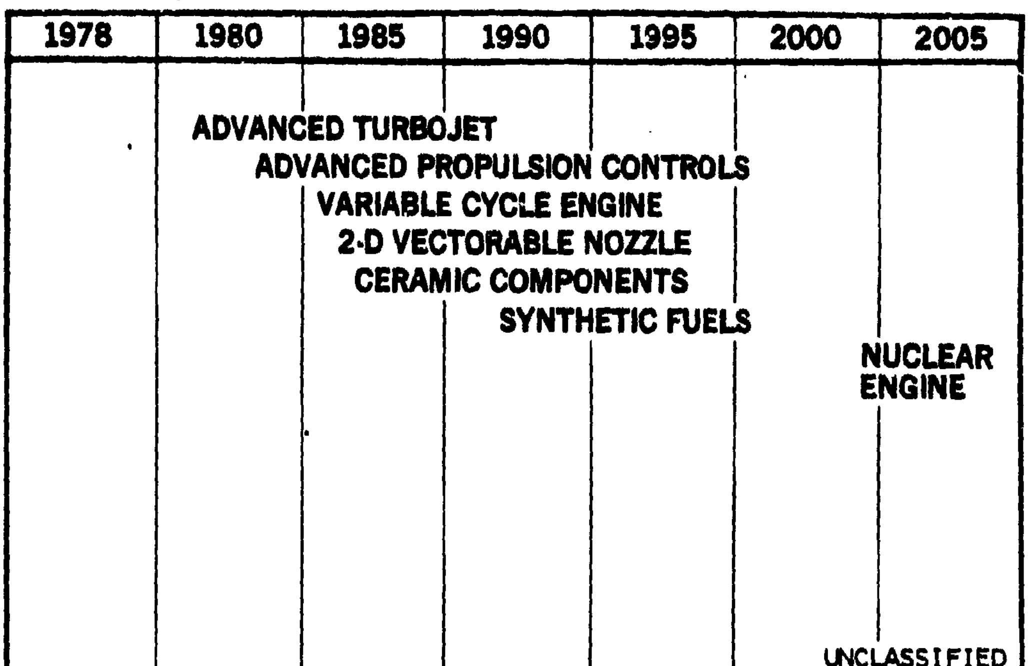
(U) Figure 27. Indirect-cycle nuclear turbojet. (U)

(U) Two radiation shield types were considered: unit shield (all shielding around the reactor) and divided shield (some shielding around the reactor, some around the crew). Because a unit shield is much heavier, the divided shield was used.

(U) In a study of large aircraft (Reference 7), a nuclear-powered aircraft was some 40-percent heavier than a kerosene-fuel aircraft carrying the same payload. This was a result of operational constraints (kerosene fuel used for takeoff and landing with reactor inoperative, plus kerosene for emergency flight). Thus, the nuclear aircraft was re-examined in this study, without imposing those operational constraints.

(U) A crucial aspect of a nuclear aircraft program is the question of safety. Routine operations can be conducted so that both workers on the program and the general public will not receive radiation doses greater than allowable. However, there is always the possibility of a crash and the resultant release of radioactivity. Some developments have been made on a crash-proof reactor and shield that will contain the radioactive material. Such a device is somewhat incompatible with the requirements for fluid and heat transfer. The weight required for the shield itself and weight needed for qrash-proofing probably can be integrated with a weight saving. In light of public attitude toward nuclear power and of the cancellation of the conventionally powered B-1, a nuclear-powered aircraft might not receive public acceptance.

(U) The projected availability dates of these propulsion technologies are summarized in figure 28.



(U) Figure 28. Propulsion technology projections. (U)

CONTROLS

(U) The ISADS basic mission involves terrain following at low altitudes for relatively long portions of the mission. The aircraft is a low load factor design which will result in highly flexible structure. The turbulence incidence is nearly 100 percent at low altitudes. These factors combine to provide a very rough ride for the crew, increased loads for the structure, and a high fatigue rate. The terrain-following requirements demand a maneuverable aircraft. The high dynamic pressure flight regime impacts the amount of structural stiffness required for flutter. Active control technology developments are providing techniques for efficiently coping with these design challenges. The active control concepts beyond the usual stability and control augmentation functions (SCAS) pertinent to this study are:

1. Ride control
2. Gust load relief
3. Fatigue rate reduction
4. Structural mode control
5. Relaxed static stability
6. Maneuver load control
7. Active flutter suppression

(U) Since ride control, gust load relief, and fatigue rate reduction are almost inseparable for purposes of this discussion, they are considered together and associated with structural mode control.

RIDE CONTROL, GUST LOAD RELIEF, AND FATIGUE RATE REDUCTION (STRUCTURAL MODE CONTROL)

(U) Ride control, gust load relief, and fatigue reduction on the fuselage are easiest to implement with small aerodynamic fins near the pilot's station. The fins should be canted 30 degrees down if both vertical and lateral structural motion is a problem. Fins could be on the aft fuselage, on some configurations, to reduce aft loads and fatigue. A lower rudder segment integrated with regular SCAS could be implemented to reduce aft side loads and fatigue rate. Part of the horizontal tail also may be used to reduce vertical gust loads and improve fatigue rate reduction. Trailing edge controls, both inboard and outboard, could be implemented to reduce gust loads and improve fatigue rate reduction on lifting surfaces. On the wing, this system could be integrated with SCAS functions and maneuver load control. Wing trailing edge controls become increasingly more difficult to implement as the wing sweep increases. These systems work mainly to damp structural modes, although some rigid body motion can be attenuated. (U)

(U) The Rockwell-developed concept of placing the sensor (an accelerometer) close to the force generator (identical location of accelerometer and force (ILAF)) would be best to use. The sensor signals are compensated to provide structural damping by the controls. On the B-1, Rockwell was able to save approximately 11 percent of the fuselage structural weight that would have otherwise been required to meet ride quality stiffness requirements beyond those resulting from strength considerations. These concepts are well developed and proven by flight test (B-1, B-52, and XB-70).

RELAXED STATIC STABILITY

(U) With highly reliable and redundant control systems, it is possible to reduce the inherent longitudinal or directional static stability required by an aircraft. This means that the possibility exists for reducing the horizontal and vertical tail sizes with a consequent reduction in wetted area drag and trim drag. Care must be exercised in integrating this concept with aircraft balance and nosewheel liftoff capability at takeoff. A recent prototype version of an improved Lockheed L-1011 was able to reduce the horizontal tail size by 20 percent over the original L-1011 tail. This concept is well developed and proven with flight test (B-52, F-16, and L-1011).

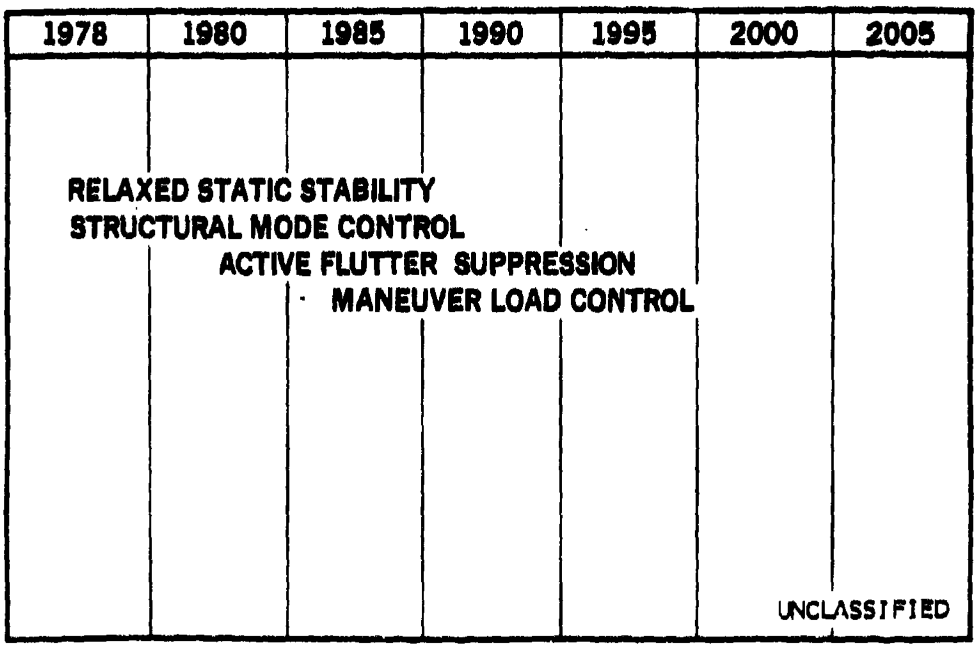
MANEUVER LOAD CONTROL

(U) Maneuver load control is used mainly to reduce the inboard wing bending moment under design maneuver conditions. This is accomplished by redistributing wing lift so that the center of pressure is moved inboard. Implementation of the concept is usually done through inboard and outboard trailing edge controls. However, this could be augmented through wing warping and elastic tailoring. The payoff could be reduced wing weight for a given wing size or increased wing aspect ratio for a given weight. The system is activated by accelerometers mounted near the nominal center of gravity. Where weight has been the prime consideration, a savings of 6 to 9 percent of wing weight has been realized in some studies. The concept could be integrated with the regular SCAS and ride control, gust load relief, and fatigue rate reduction systems. This concept becomes worth less and more difficult to implement as the wing is swept aft. This concept is relatively well developed and flight tested (B-52, C-5, and L-1011).

ACTIVE FLUTTER SUPPRESSION

(U) This concept is similar to those used to provide ride quality, gust load relief, and fatigue rate reductions. Structural motion is sensed (accelerometers seem best) and controlled through leading edge and/or trailing edge control surfaces on the lifting surface involved. ILAF implementation would be appropriate. Structural damping and frequencies are altered to prevent flutter. The most conservative use of the approach would be to build the lifting surface stiff enough to meet maximum speed flutter requirements and provide the margin requirements with the control system. The less conservative approach would be to design the wing for flexible wingloads and static stability. Having done this, it is likely that the flutter boundary would be within the flight envelope. Thus, the active flutter suppression system would be required to provide flutter-free flight up to maximum speeds plus the required margin. This system demands high reliability. As the lifting surface is swept, the ability to implement this concept becomes less. Fortunately, as the lifting surface is swept there is less need for a flutter suppression device. This concept is the least advanced of all active controls discussed, and further development work is required. The concept, however, has been flight tested for lightly damped flutter modes (B-52). The concept is currently being explored in wind tunnels (AFFDL and NASA) and on drones (DAST/NASA) for highly divergent flutter situations.

(U) The projected availability dates of these controls technologies are summarized in Figure 29.



(U) Figure 29. Controls technology projections. (U)

STEALTH

(U) Reduction of aircraft observables for high-performance vehicles starts with attempts to minimize the radar cross section. The second priority is given to IR suppression, and the next consideration is visual camouflage. Other observables such as noise, laser cross section, and ultraviolet cross section are deemed to be of considerably lesser importance and currently do not warrant any aircraft penalty or expense. Visual stealth is also a primary consideration for low-performance aircraft. The detection threats are radar, infrared, and, to a lesser extent, visual. Hostile missile guidance uses radar and IR.

(U) It is highly doubtful that any of the current threats will have evaporated by 1995. It is possible, however, that one or more of the lower ranking observables, such as laser cross section, will be a matter of great concern at that time. Reduction of laser cross section, however, will probably be accomplished by techniques (such as shaping and surface finish control) that are related to suppression of other electromagnetic signals. Consequently, since the threats are likely to be broader and more intense in 1995, the stealth design efforts will be more critical and will yield greater payoffs. The principal payoff for successful stealth design is the ultimate reward, survivability, but there are additional payoffs in the areas of reduction of gross weight, reduced complexity, lower cost, and reduction in logistics requirements.

RADAR CROSS SECTION (RCS)

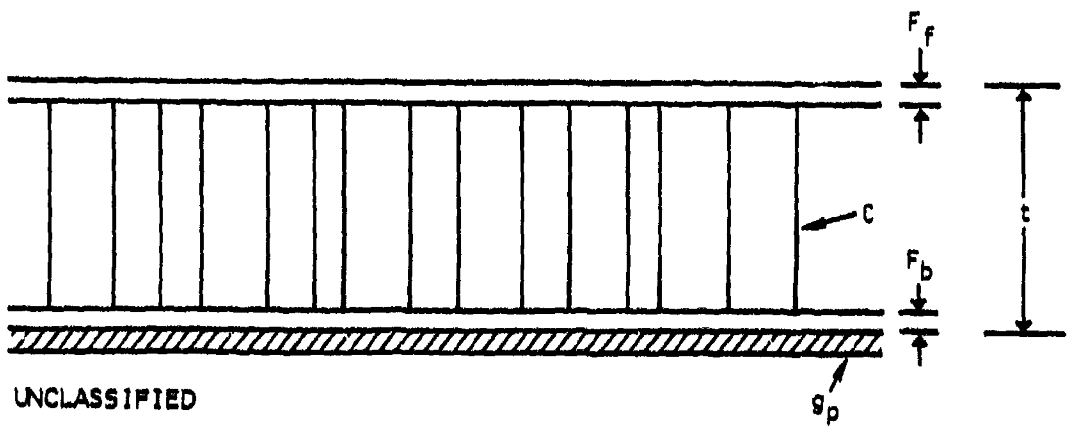
(U) The techniques used for RCS reduction are variations on the twin themes of reflection (in directions away from the radar receiver) and absorption. Improvements in materials continually advance the effectiveness of absorber systems. The area of current greatest progress is the development of structural radar-absorbant material (RAM) systems which are used in aircraft cavities such as inlet ducts and antenna cavities.

(U) RAM materials comprise two general types: structural and parasitic. Structural RAM may replace existing structure and thus will carry the necessary loads while simultaneously serving as a radar absorber. Parasitic RAM, as the name implies, is applied over an existing structure and has little or no useful structural properties.

Structural Absorbing Systems

(U) The basic structural elements are dielectric materials into which electrically active elements are positioned. The electrical elements may be in the form of sheet material or an additive that makes the normal components electrically lossy. Sheet materials usually involve a multilayered system to achieve the magnitude of loss desired which results in somewhat lower structural properties and increase weight. These systems are best used in special limited applications where very high values of absorption are required. The additive materials usually involve single-core systems with an electrically lossy core. These are the primary candidate systems for inlet application since they are the most similar to normal structure and have the same strength and weight. (U)

(U) A single-core RAM system is shown in Figure 30. For frequency coverage down through S-band (2 GHz), t is nominally 1-inch minimum with no upper limit and may be varied indiscriminately for t's greater than 1 inch. C is typically a heat-resistant phenolic 3/16-inch cell of 3 to 8 pounds density, and gp is a reflective sheet of either aluminum foil or fine-mesh screen used as a ground plane to terminate the absorber. F_f and F_b are the front and rear glass filament reinforced resin facings which, with the overall core thickness, make up the basic structure. As a single laminate, F_f is limited to roughly 0.05 to 0.06 inch to maintain high absorptivity of specular incidence. The radar-absorptive properties are obtained by specially treating the core with a carbon/resin coating that has a weight of approximately 0.03 pounds per board foot.



(U) Figure 30. Single core RAM system. (U)

(U) The core may be a single layer of lossy spacer or may be graded in the direction of the ground plane.

Materials for Structural Absorbing Systems

(U) With the exception of the ground plane, all materials which are used in the absorber must be dielectric. The ground plane is usually of conductive material through which an electric field will not propagate. The remainder of the absorber passes or absorbs part or all of the incident radiation.

Skins

(U) For lightweight structures, skin-core sandwich is usually used. In this case, the skins are the basic load-carrying elements as well as the source for most of the weight of the structure. Most of the structures to date have been made from resin-fiberglass systems where the resin is selected according to the expected environment of the part. Epoxy, phenolic, and polyimide resins have been used to bind glass which is either woven or in the form of unidirectional multistrand. Where maximum front face transparency is a factor, skins have been made from quartz fabric bonded with polyimide resin.

(U) Advanced composites are being developed which include graphite, boron, and PRD-49 (DuPont) as replacements for fiberglass and quartz. These materials have favorable stiffness properties along with high specific strength. PRD-49 is eminently suitable for RAM purposes because it has both a low dielectric constant and low loss tangent. RAM systems have been prepared using these skins with absorption values as good or better than fiberglass.

(U) Graphite and boron, however, are electrically conductive and cannot be used as the skin on which the energy impinges. The back skin, which is a conductive ground plane, can be made from graphite or boron and will work as well as metal.

Cores

(U) Various materials may be used for core spacers, including glass epoxy, glass-phenolic, and glass-polyimide as candidates. Metal core appears the same as a sheet of metal when viewed by the radar field and therefore cannot be used as a spacer.

(U) For lossy core absorbers, the core selection is made based upon load requirements and the core is overcoated with a resin-pigment system which imparts a lossy characteristic to the core. This has much less conductivity than metal core.

Adhesives

(U) Adhesives are required to bond the various components together. These adhesives need to be suitable to the end-use environment but cannot contain metal fillers since these would interfere with the proper interaction of the electrical elements during absorption.

Structural Design Considerations

(U) Fundamentally, structural design of absorbing systems is identical with the counterpart nonabsorbing structure. In the case of skins, solid-laminate spacers, and lossy core absorbers, these components are the same as in any other sandwich; therefore, design allowables for these components are directly derived from general material considerations.

Bonding

(U) Coating of the core with the carbon/resin mixture, which is the only deviation from standard structure, has no effect on bonding properties. However, in case of doubt, the coating can be masked from the adhesive fillet area by a lost wax-type process.

Temperature

(U) The resin/carbon core coating mixture, which again is the only deviation from standard structure, will not be affected by temperature if the resin carrier is selected for its temperature properties, which would be the same as the remainder of the structure.

Moisture and Humidity

(U) The effect of excess moisture absorption is a change in electromagnetic properties as well as some degradation in the structural properties. The high dielectric constant of water (80 compared to 4 for most glass-resin systems) changes the electrical response of the absorber. Resins that possess good resistance against extreme weather conditions should be used in conjunction with external surface sealant to limit moisture absorption.

Panel Design

(U) Figure 30 showed a typical inlet RAM panel construction that employs the preceding principles. The front face sheet, honeycomb core, and front adhesive line are the only components that need be fabricated from dielectric materials. All other parts can be of any suitable material. If the panel rear face sheet is made from an electrically nonconducting material, then a conducting ground plane must be incorporated (aluminum foil, wire screen, etc) on either the front or rear surface (or in between) of this face sheet.

1995 Technology

(U) The greatest advancement to be expected in the area of structural absorber systems is an increase in the frequency range of highly absorptive systems. At the present time, there is a trade-off between these two properties, with the most highly absorptive materials not available at the higher frequencies. Given the current accelerating interest in structural absorber systems development, it is reasonable to expect an increase from 10 dB reduction to between 20 and 30 dB reduction for the broad-range, load-carrying RAM.

Nonload-Carrying Absorbers

(U) Structural absorber systems have not yet been developed which will withstand the engine exhaust nozzle environments. Parasitic absorber installations, such as ceramics, carry a weight penalty. Magnetic absorbers, tend to become demagnetized at high temperature and lose their absorptive properties. This then becomes the area of greatest improvement in RAM to be expected by 1995.

(U) The RAM for exhaust systems use must endure the severe environment of the nozzle with respect to high temperature, thermal shock, oxidation, and vibration, as well as functioning as a microwave absorber at high temperatures. The Air Force Avionics Laboratory has been sponsoring developments in this field (Reference 8), and there is room for much progress.

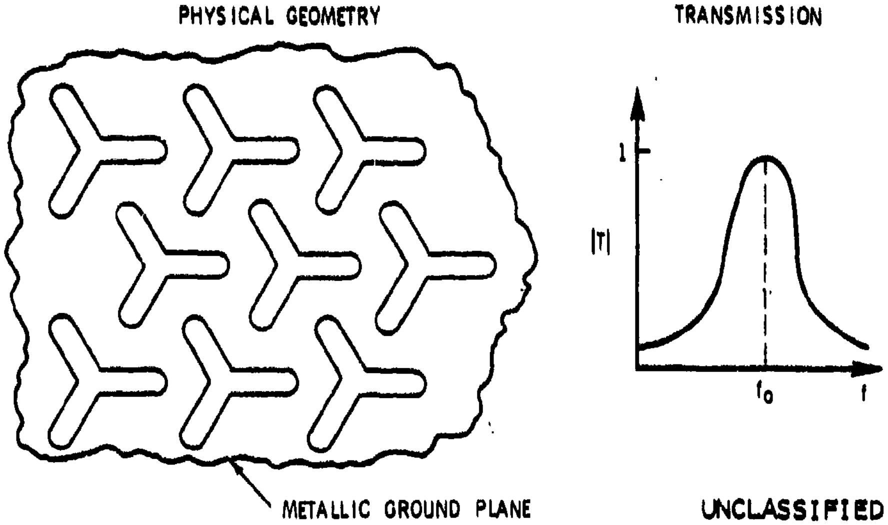
(U) Another parasitic absorber application is the use of magnetic materials on wing and other airframe surfaces to absorb traveling waves which reflect from discontinuities in the surfaces, such as wing trailing edges. The heavy weight (up to 1 psf) of this material inhibits its use at the present time. Material developments can be predicted for this area also.

Geometry Control

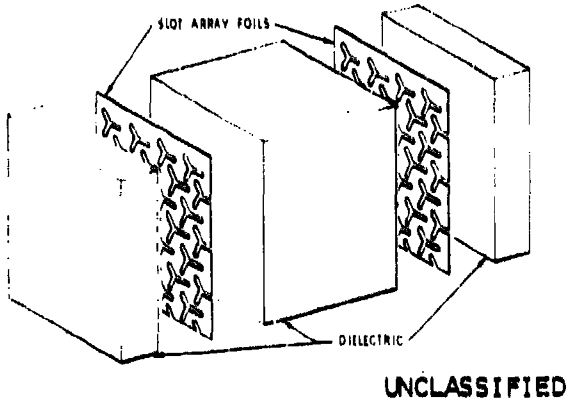
(U) The reflection principle is used in varied applications on aircraft to reduce RCS. Planar retreating surfaces are used, where possible, to induce a specular return away from the receiver. Corner reflectors are eliminated, and gaps and cracks are filled with absorbing or metallized seals. Transparencies such as the cockpit enclosure, are gold flashed to completely hide the cavity. Reflecting or absorbing vanes may be used in the engine inlet cavities, in conjunction with structural RAM, to prevent direct reflection from the front face of the engine. These techniques are important at this time and will still be important in 1995, but it is difficult to postulate improvements in them, since the techniques work well now when sufficient time is applied to them before the vehicle design is fixed.

Tuned Radomes

(U) A new development is the use of tuned, or selective frequency, radomes which permit only the narrow band used by the aircraft radar system to pass and present a reflective metal surface to all other frequencies. The geometry of the ground plane and the transmission characteristics are as shown in Figure 31, and the construction characteristics are shown in Figure 32. This technology will almost certainly be matured and in operation by 1995.



(U) Figure 31. Resonant slot array characteristics. (U)



(U) Figure 32. Detailed wall construction. (U)

RCS Prediction Methods

(U) The lack of accurate analytical models for aircraft RCS prediction has been a critical technology void. Up to the present time, it is still faster and cheaper to fabricate RCS models, test them on a range or in an anechoic chamber, and then reduce the data than it is to use the best current analytical models. This is because the analytical models are both slow and are capable of caclulating only the simplest geometries, particularly with respect to the important inlet and nozzle cavities. New-generation digital computers and increased emphasis on vehicle stealth design make this an area for predictable improvements. When the analytical methods are available, the demonstrated geometry methods of RCS reduction will be easier to apply early in the design process.

IR SUPPRESSION

(U) For high-performance aircraft, the IR signature is a function of both the system operation and the design. Higher engine power settings increase the emission from the hot metal parts of the exhaust system and from the engine plume. Sustained high velocity results in significant IR emission from the entire aircraft skin, particularly in the longer wavelength bands that are used by the new IR-seeking missiles. Design features that impact the IR signature include the selection of engine cycle, the exhaust system and augmenter design, and the surface coating used on the aircraft skin. IR suppression techniques of shielding, cooling, and emissivity control may be applied to these aspects of aircraft design.

(U) For a low-altitude penetrator in the 1995 time frame, detection from space vehicles is a prime hazard. The airplane skin radiation would be limited by using an external paint that simultaneously provides low IR emissivity and high resistance to nuclear flash. Silicon binder materials (Reference 9) yield a 50-percent reduction in IR emissivity compared to current aircraft paints. Further improvements in the reflectivity can be assumed for 1995. To minimize the engine hot part and engine plume IR emission, a 2-D exhaust nozzle with an upper external ramp surface, such as the GE ALBEN nozzle, should be used. A 2-D nozzle of 4 (or more) aspect ratio suppresses the plume emission during nonaugmented operation and denies viewing up the tailpipe of the hot metal parts of the exhaust system. (If rear aspect IR emission is the significant consideration, a 2-D plug nozzle should be used as the suppressor.) To provide cooling air for the shielding surfaces and to further dissipate plume radiation, the engine bypass ratio should be as high as is practical. A limiting factor on the bypass ratio is that it increases the engine inlet size and therefore may aggravate the RCS reduction problem.

(U) The shielding, cooling, and emissivity control methods of IR suppression will probably still be applicable in 1995. Advancements will probably be pronounced in the improvement of the nozzle suppressor designs using internal blockage devices that hide the turbine from view. Hydrogen fuels would eliminate the carbon dioxide radiation at 4.3 microns, which is the principal radiation source during afterburner operation, but the IR problem would still remain due to the other sources. Use of aerosol injectants or other expendable suppression techniques is not likely to be feasible for a long-range aircraft. (U)

STRUCTURE - AIRFRAME CONCEPTS

(U) The goals for the airframe structure of the strategic aircraft of the post-1995 time period are clear. They must be less expensive, lighter, contribute to the survivability of the whole aircraft, be more durable with respect to service life, be less expensive to maintain, and be more easily repaired. This will require new structure design and fabrication technology in order to move the Air Force and the industry closer toward closing the requirement/cost gap for future strategic systems.

(U) To accomplish these goals, the use and development of new materials and processes that can contribute significantly to the challenge of "materials" manufacturing must be accomplished. This will require exploitation and development of existing materials, new materials, and material combinations to the extent required to significantly reduce end-item acquisition costs.

MATERIALS

State-of-the-Art

(U) Material systems in use for current aircraft structure can be separated into three categories of materials:

1. Advanced composite maerials encompassing the family of fiber-reinforced organic matrix materials
2. Metal materials, normally titanium, aluminum or steel
3. Metal matrix materials encompassing the family of fiber-reinforced metal matrix material combinations

Advanced Composite

(U) Advanced composite materials have emerged from the laboratory to become materials with application to production airframe structures. Other composite materials such as boron/tungsten filament or Kevlar fiber-reinforced organic matrix materials have had limited incorporation on existing airframes, as have polyimide-resin fiber-reinforced materials, except for radome applications.

Metallic Materials

(U) For titanium, particular emphasis has been placed on reducing manufacturing costs while maximizing aircraft performance (weight reduction) through the development of diffusion bonding and concurrent superplastic forming/diffusion bonding technologies.

Metal Matrix

(U) These advanced composite materials have been slow in developing into viable materials for use on existing aircraft, primarily due to the reduced mission requirements of today's aircraft systems. Comprised of directionally oriented, high-strength, high-modulus continuous filaments entrapped within a metal matrix, these materials offer the designer flexibility through tailoring of strength and stiffness while maintaining the damage tolerance and environmental characteristics of metal structures.

Projected Technology - 1995 and Beyond

(U) The designer of post-1995 airframes will have available a wide range of materials to choose from that will have lower cost, lower weight, and improved maintainability characteristics as technology improvements and developments accrue during the next 20 years.

Advanced Composite

(U) In the field of advanced composite materials, current developments in processing of net-molded advanced composite parts demonstrate that net molding will be a standard process for the 1995 airframe and, when coupled with use of low-bleed or zero-bleed prepregs, will produce parts with a minimum of material waste and fabrication hours.

Metallic Materials

(U) Metallic materials for airframe use will be selected to maximize service life. Special considerations will be given to toughness characteristics of the materials and to the resistance of various types of corrosion.

(U) Recent developments have resulted in new aluminum alloys such as 2048-T851, 7050-T76, and 7475-T76, which had limited application on existing aircraft but should be available for post-1995 aircraft. 2219-T851, an existing material, will be used where welding is required. Of the emerging alloys, 2048-T851 will be used where welding is required and for tension skins where thickness is over 1.5 inches or where exposed to temporatures over 250° F. 7075-T76 and 7475-T76 will be used at temperatures below 250° F, where high compression yield is required. 7475-T76 will also be used for its high fracture toughness properties. Aluminum sheet material such as M67-T7E71, made out of powdered metallurgy billets, will be used where high tension or compression properties are required. Properties for these alloys are shown in Table 6. Dispersion-strengthened aluminum alloys with strength properties equivalent to those of M67-T7E71, but with improved fatigue, crack growth, fracture toughness, expoliation, and stress corrosion resistance, will compete for application where titanium is used today. (U)

(U) TABLE 6. CANDIDATE ALUMINUM ALLOYS FOR 1995 (U)

Property	2048 T851	2219 T851	7050 T76	7475 T76	M67 T7E71 PM
F_{tu} (ksi)	62	62	72	71	87
F_{ty} (ksi)	56	35	62	61	81
F_{cy} (ksi)	56	45	64	63	81
K_{Ic}	33	33	30	40	25
E (X 10^6 psi)	11.3	10.5	10.2	10.3	10.6
Stress-corr resistance	Good	Excell	Good	Good	Good
ρ (lb/in.^{3})	0.099	0.102	0.102	0.101	0.104

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(U) Recent experiments have produced an aluminum sheet product with substantially improved strength properties. The process appears to be applicable to all conventional, precipitation hardenable aluminum alloys. There is potential for improved fatigue strength as well as superplastic forming capability.

(U) For titanium alloys, it is easy to project that by 1995 the emerging alloys of Ti-10V-2F3-3Al and Corona -5 (Ti-4.5Al-5Mo-1.5 Cr) in thick sections will be commonplace in aircraft manufacture. Corona -5 STA is especially desirable because of its high fracture toughness and its air-cool quench process, making it compatible with diffusion bonding. Thin-sheet titanium candidates (triplex annealed Ti-6Al-2Sn-4Zn-6Mo, Ti-15V-3Cr-3Al-3Sn, and Ti-10V-2Fe-3Al) are selected because of their high strength, high stiffness-to-weight ratios, and forming capability. Textured titanium products will offer 25- to 30-percent improvement in modulus and strength properties in the longitudinal direction, with little or no degradation of transverse properties. Textured properties have been demonstrated for Ti 6-4 and Ti-6-2-4-6 alloys. Properties for these titanium alloys are shown in Table 7. (U)

(U) It is also projected that new titanium processes such as hot isostatically pressed powder metallurgy parts, flow forming, and isothermal forging technology will have reached a level of maturity for incorporation on post-1995 aircraft, supplementing superplastic forming/diffusion bonding options which are in application status on today's airframes.

(U) TABLE 7. CANDIDATE TITANIUM ALLOYS FOR 1995 (U)

	Thick section		Thin sheet				
	Corona -5 sta	Ti-10-2-3 sta	Ti-6-2-4-6 Tri-ann	Ti-15-3-3-3 sta	Ti-10-2-3 sta	Textured Ti alloy (L)	Textured Ti alloy (T)
F_{tu} (ksi)	180	175	195	190	170	200	160
F_{ty} (ksi)	170	165	185	180	165	185	145
F_{cy} (ksi)			190	185	160	195	155
E (X 10^6 psi)	16.0	14.0	17.0	17.0	15.0	18.5	16.0
E_c (X 10^6 psi)			17.5	17.5	15.5	19.0	16.5
Elong (%)			7	6.0	10.0	6.0	10.0
ρ (lb/in.^{3})	0.164	0.168	0.169	0.172	0.168		
F_{tu}/ρ (X 10^6 in.)			1.154	1.104	1.012		
E_c/ρ (X 10^6 in.)			1.035	1.017	.923		
K_{Ic} (ksi $\sqrt{in.}$)	75	65					
da/dn (X 10^{-6} 1 pc)							
@ΔK=10 ksi $\sqrt{in.}$	.2	2.0					
@ΔK=20 ksi $\sqrt{in.}$	6.0	20.0					
@ΔK=40 ksi $\sqrt{in.}$	65.0	70.0					
K_{Iscc} (ksi $\sqrt{in.}$)	75	70					

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Metal Matrix

(U) In the metal matrix field, one of the most promising fiber developments which should see full-scale production experience by 1995 is carbon-core silicon-carbide fibers. Effectively chemically inert and capable of withstanding molten aluminum temperatures without appreciable strength losses, current technology investigations include continuous filament-reinforced castings. Although in their early stages of development, current wetting tests (fiber dippling in molten metal) show longitudinal strengths far in excess of the rule of mixtures principle, and continuous-tape preform concepts are already under laboratory investigation by Rockwell. If proven successful, cost projection of filament-reinforced cast structure may show the first example of metal-matrix advanced technology cost-competitive with conventional sheet metal construction.

Improved Technology Payoffs

(U) Improved technology will show payoffs in the form of decreased cost and weight of 1995 aircraft designed to perform a specified mission. This will be accomplished by means of improved weight/strength ratios, higher design allowables due to lower data scatter, and damage-tolerance enhancement. The improved payoffs thus will lead to mission completion enhancement and improved buy-to-fly ratios.

(U) Two types of improvements are foreseen for advanced composites. Improved production processes will lead to a more reliable achievement of the higher end of Rockwell's present data scatter, thus leading to higher design allowables. Increased use will lead to less conservatism in design, especially in the area of joints and environmental effects, with resultant lower cost, both for the material and the manufactured product.

(U) For metallic structures, improved fabrication processes such as superplastic-formed/diffusion bonding can lead to weight/cost-effective sandwich construction heretofore unattainable.

(U) Integral structures construction (i.e., reduction in complexity and the number of joints) and the domino effect (i.e., reduction in structural mass leads to reduction in power/plane weight leads to reduction in structural mass...) will also inevitably lead to more weight/cost-efficient structures.

(U) In conclusion, it is anticipated that aircraft weight and cost reductions of 30 to 50 percent are entirely feasible.

Materials Technology

Group 1 - Advanced Composites

(U) Areas where advanced composite technology development or improvement must be accomplished are:

1. Development and mechanical property characterization of commercial-grade graphite, boron, and Kevlar fibers in unidirectional tapes, woven fabrics, and broadgoods

2. Development and characterization of resin systems, both epoxy based and polyimide based, that have substantially increased resistance to moisture degradation

3. Development of polyimide resin systems with processing characteristics similar to epoxy resins to permit wide-spread application to post-1995 airframes

4. Development of graphite/epoxy-reinforced honeycomb core to permit the use of full-depth honeycomb sandwich structure to be used on post-1995 airframes free of the corrosion problems plaguing aluminum core applications today and with higher strength-to-weight ratios that exist for today's glass-reinforced (HRP) core. The following hybrid and thermoplastic matrix advanced composite honeycomb cores have been selected for development or improvement in current programs:

   a. Expanded hybrid HFT, GY-70 graphite (600 fibers per tow)/fiberglass at yarn end ratio of 1 GY-70/5 glass, 3/16-inch cell size, 4.5 pcf target density, phenolic resin matrix

   b. Expanded hybrid HFT, T-300 graphite (1,000 tow)/fibegglass at yard end ratio of 1-T-300/t glass, 3/16-inch cell size, 5 pcf target density, phenolic resin matrix

   c. Corrugated HFT reinforced with GY-70 graphite/fiberglass hybrid interleaf, 3/16-inch cell size, 7.5 pcf target density

   d. Corrugated GY-70 graphite ±45-degree unidirectional/polysulfone, experimental honeycomb core, 3/16-inch cell size, 8.6 pcf target density

   e. Expanded 24 by 24 bidirectional, T-300 graphite (1,000 tow) fabric/polysulfone matrix, experimental honeycomb core, 3/16-inch cell size, 8 pcf target density

   These cores offer great potential in terms of improved normal shear stiffness, a key property in the stabilization of composite sandwich panels. Cores a. through c. offer a theoretical shear stiffness potential of approximately two times that of standard HFT core of similar density; cores d. and e. approximately five times that of standard HFT core.

5. Development and mechanical property characterization of boron-carbon filament fibers for replacement of the higher cost boron-tungsten filaments fibers in use today (U)

(U) In addition to the preceding developments, it is reasonable to predict that technology developments in the pre-1995 time frame will develop fiber-reinforced thermoplastic materials, low-density fiber-reinforced foams, and heat-formable pultrusions into viable material options for the designer of post-1995 airframes.

Group 2 - Metals

Aluminum. (U) Material technologies which require additional development are:

1. Continued technology development for new aluminum alloys such as 7475, 2048, and 7050

2. Expansion of mechanical property data base for new alloys, permitting early application to production airframes

3. Continued development of the high-strength aluminum process to establish design properties of mill-produced products

4. Development of tailored composite (dispersion-strengthened) alloys to fill specific requirements such as temperature and/or mechanical properties

5. Development of manufacturing methods for small and large net precision forgings and castings

6. Development of arc seam welding as a primary assembly method

Titanium. (U) Areas where technology development or improvement should be continued during the pre-1995 time period to realize the full potential of titanium applications on post-1995 aircraft are:

1. Near-Net diffusion Bonding - Diffusion bonding is a process for making large, complex titanium structural parts as well as smaller fittings. It lends itself well to fabrication of complex pockets, intricate webs, and thin sections. Use of the process can result in substantial cost savings over competitive machined forgings, machined plate, or weldments. Cost-reduction advancements in the process include improved fly-to-buy ratios becasue of closer-to-net bonded parts, reduced press time, reduced inspection requirements, and improved tooling.

2. Concurrent Superplastic Forming/Diffusion Bonding - This is a process for producing severely formed sheet metal details by using the unique high tensile elongation properties of titanium within the superplastic temperature range. The process is applicable to titanium sheet metal parts having complex combinations of shrink and stretch flanges, beads, compound contours, and short-bend radii. Bend radii equal to the metal thickness (1t) are readily achievable with close tolerances and freedom from residual stresses. Recent developments allow use of integral pad-up areas that can be added by concurrent forming and diffusion bonding of added strips or pads, resulting in

integrally stiffened areas. The production of multiple parts in a single processing cycle is a major advantage of the process. Significant reduction in design constraints is possible due to the superplastic forming process by greatly extending the forming capability such that joints and fasteners may be eliminated by combining two or more details.

3. Sine Wave Welding - Sine wave welding is a unique method for producing thin-gage, highly efficient titanium and steel beam components requiring high strength and stiffness. It is particularly attractive for lightweight spars, ribs, and longerons where joining caps to webs is required. New advancements in the process permit fabrication of distortion-free parts over 12 feet long, using very-low-cost tooling methods. Studies have been instituted which should be continued to apply the process to metals other than titanium.

4. Flow Forming - Integrally stiffened panels can be produced in titanium by flow forming material into a shaped die to form stiffeners and projections up to a height of 1-1/2 to 2 inches. Major cost savings result from eliminating much of the as-purchased material weight and the cost of its subsequent removal by machining. The process employs existing equipment and methods but extends size range from that applicable to conventional forgings. The product provides high metallurgical quality and can be subsequently welded or formed to produce a great variety of configurations.

5. Isothermal Forging - Isothermal forging of titanium is being developed to provide essentially net parts which require a minimum amount of machining, generally only on interface surfaces. Parts are limited by size and geometry, should be symmetrical about the forging parting line, and can be produced in rate production quantities. Advantages to this process include (1) close tolerances, (2) no draft on walls perpendicular to the parting plane, (3) small corner and fillet radii, (4) reduced buy weight, and (5) reduction in machining required.

6. Brazed and Welded Sandwich Structures - Sandwich structures have three discrete structural elements: two face sheets and one core. The face sheets carry loads in the plane of the sandwich and are stabilized by the core. The core, which may be honeycomb, corrugated, or other configurations, carries loads normal to the plane of the sandwich. The face sheets are joined to the core by brazing or welding to make up the sandwich assemblies, which exhibit the following advantages:

   a. High strength/weight ratio

   b. High stiffness/weight ratio (U)

c. Thin-sheet stabilization to high stress levels

d. Substructure minimization

e. Aerodynamic smoothness

f. High sonic fatigue resistance

g. High thermal gradient capability

Metal sandwich can be made from any weldable material and is actually a composite of many elements joined together at node interfaces by welding, brazing, and/or diffusion bonding. The technology gained during the B-70 program should be extended to include the new titanium alloys, making all titanium sandwich structures viable for post-1995 strategic aircraft. (U)

Group 3 - Metal Matrix

(U) For metal matrix materials to realize competitive economics with other post-1995 material selection candidates, research and development activities should be continued in the following areas:

1. Technology improvement for infusion casting and mechanical property characterization of the following metal matrix material combinations:

Metal Matrixes	Reinforcement Filaments
Aluminum	Boron/carbon
Titanium	Silicon carbide
Beryllium	Coated fibers

2. Technology improvement for diffusion bonding of fiber-reinforced metal matrices and mechanical property characterization:

Matrix Material	Reinforcement Filaments
Aluminum	Boron
	Silicone carbide
	Graphite
Titanium	Tungsten
	Copper
	Other filaments

3. Development of improved manufacturing methodology to reduce acquisition costs of fiber-reinforced metal matrix materials. Avenues of investigation should include tooling cost reduction, filament cost reduction, development of welding as a primary assembly technique, and extension of fiber reinforcement technology in large superplastic forming/diffusion bonding primary and secondary structure applications. (U)

Materials - Hostile Environment Protection

(U) Strategic aircraft of the post-1995 time period will be exposed to external weapons threats of differing degrees and magnitudes than for today's aircraft as weapons technology develops concurrently with materials technology. It is anticipated that passive protection systems will be employed on the external surfaces of aircraft structure to enhance the survivability/vulnerability (S/V) performance of post-1995 strategic aircraft. The susceptibility of airframe structural materials to laser weapon and nuclear weapons effects will be evaluated, with primary emphasis on establishing the direction of future technology development to counter the effects of laser weaponry.

Laser Weapons

(U) The mechanisms of target damage and kill must be defined, and the characteristics of potential weapons must be quantitatively analyzed to establish guidelines for the development and direction of passive protection systems. For lasers, the spot size, power density, wave length of incident energy, and time history of target acquisition must be analyzed. Quantitative analysis will be performed with an end objective of confining laser weapons damage to the external surfaces of both nonmetallic and metallic structural airframe surfaces. Particular emphasis will be placed on addressing protection systems for areas of the aircraft where through-skin penetration could cause loss of aircraft. Such areas would include fuel cells and the fuel transfer systems, as well as crew compartments. The studies performed would also address prevention of ignition after an assumed burnthrough of the external skin and protection system(s).

Nuclear Weapons

(U) The nuclear weapons threat (i.e., blast temperature, blast pressure, and electromagnetic pulse threats for airframe structural materials) has been evaluated and documented for a current strategic aircraft and, except for canopies and electrically transparent structure (radomes, antenna enclosures), protection systems are available for post-1995 aircraft. These protection systems will not provide protection against the higher incident energy levels associated with laser weapons predicted for the post-1995 time frame.

Vehicle Signature Reduction

(U) An investigation of materials and techniques for infrared signature reduction is required for anticipated hot regions of the aircraft as well as evaluating materials and methodology for reducing the radar cross section of post-1995 aircraft. These studies should springboard from the methodologies used on current strategic aircraft and predictions and trends in methodology for future aircraft. Materials for infrared and radar cross-section (RCS) signature reduction will require analyses for compatibility with the requirements of materials or material systems selected to counter the laser and nuclear weapons threat.

Protective Coatings (Systems)

(U) New protective coatings for aircraft exterior surfaces will require development to meet the protection requirements of the post-1995 strategic aircraft. These coatings will be tailored to enhance resistance to hostile environment characteristics produced by nuclear and laser weapons, and they may be designed to reduce IR signature and RCS by taking advantage of the spectrum windows that occur in various organic and inorganic materials.

Current passive protection system philosophy is evolving along the lines of multilayer organic and metallic films applied to the external surfaces of airframe structure to simultaneously counter multiple threats. These protection systems lend themselves more readily to the protection of advanced composite structural surfaces; consequently, evaluation and technology developments in protection systems for advance composite structure are of primary importance.

Structure

(U) Two types of structure have been considered in this evaluation: (1) basic structure, which is designed to serve in a normal environment, and carry conventional airframe loads, and (2) special-purpose structure, which is designed to operate in a hostile environment such as nuclear burst or to serve in a unique capacity such as RCS reduction or laminar flow control (LFC) in addition to reacting flight loads.

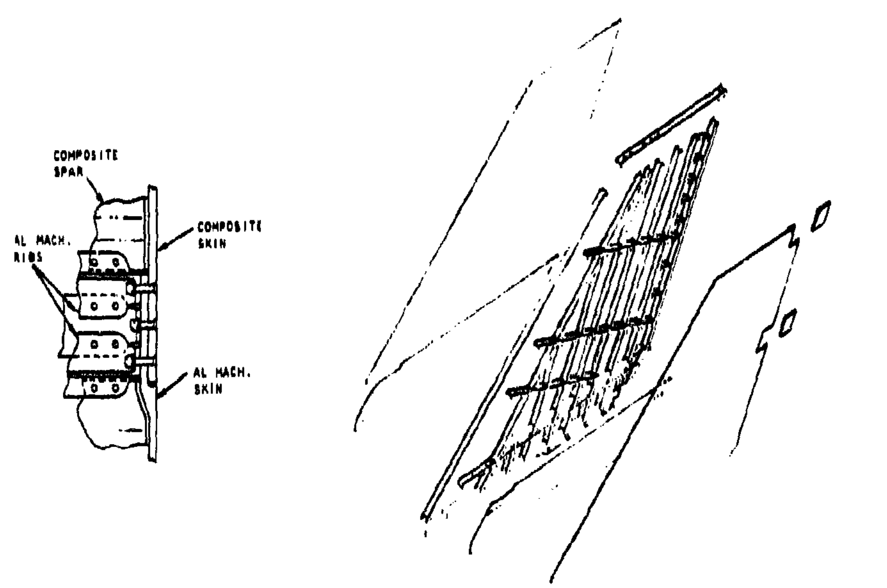
<u>State-of-the-Art (1977)</u>

Basic Structure

(U) Currently, most primary structures are metallic constructions. The wings and empennage are normally mechanically fastened skin and stringer/rib or multispar constructions. Aluminum is used for the machined skin and substructure details, although titanium sine wave beams have been used for empennage substructure in conjunction with a machined aluminum skin on current aircraft designs. (U)

(U) Fuselage constructions are aluminum skins with stiffeners mechanically attached to frames. The aluminum skins are stiffened by the addition of riveted, bolted, or bonded hat, zee, or tee sections. There is increasing use of aluminum, integrally stiffened, monolithic components for primary fuselage structure that additionally functions as a fuel barrier. These parts are produced out of plate or large forgings, using numerically controlled machine operations. A substantial cost reduction is accomplished through minimizing the number of detail parts fabricated as well as the number of man-hours required to apply the fuel sealing material. The reduction of the amount of fuel sealing material used results in an effective weight reduction. Where temperature requirements or high fracture toughness requirements are of primary concern, titanium is used in lieu of aluminum. Examples of current titanium applications are longerons, wing carry-throughs, diffusion-bonded frames and bulkheads, and superplastic-formed/diffusion-bonded beams and doors.

(U) Advance composite materials are being used in empennage primary structure for both structural skin and substructure details (Figure 33). In this application, the advance composite parts are used in substitution for an existing metal design and follow the same construction pattern. Despite this drawback, weight and cost savings of 15 to 20 percent are being realized for the advance composite structure.



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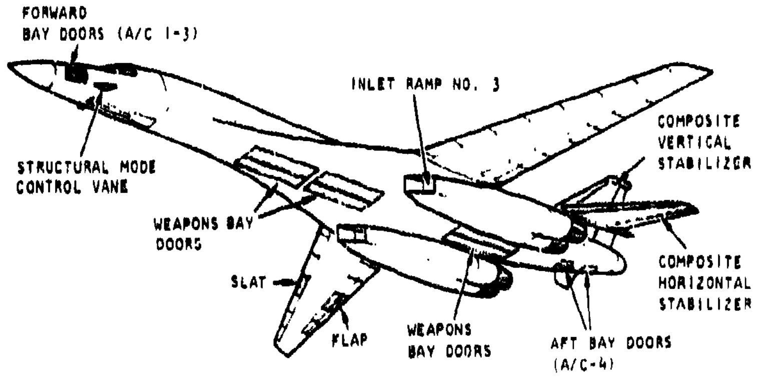
(U) Figure 33. Advanced composites utilization in empennage. (U)

(U) Primary structure fabricated from metal matrix materials has not found application on current aircraft to date. Studies have shown, however, that a B-1 wing root rib fabricated from metal matrix (boron/aluminum) when compared with its titanium counterpart demonstrated a 33-percent weight savings and 45-percent average unit cost savings. A wing root rib from boron/aluminum was successfully fabricated and tested to demonstrate the technology under Air Force Contract F33615-74-C-5151, Manufacturing Methods for Metal Matrix Structural Components.

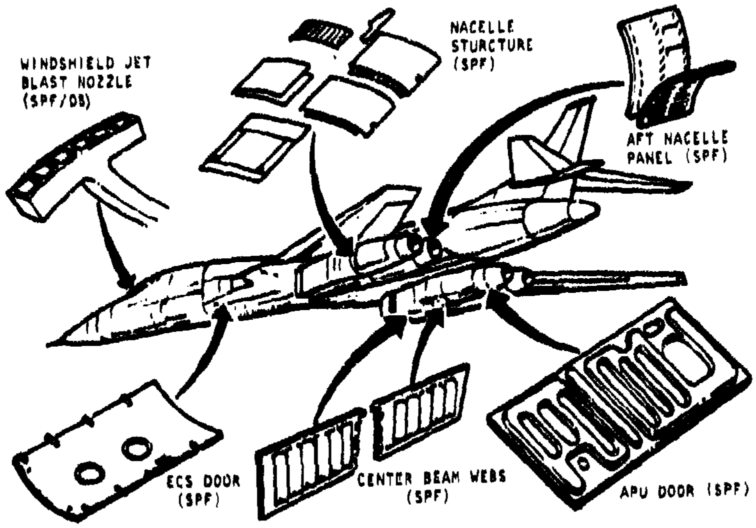
(U) Most secondary airframe structures are either aluminum skin/rib/stringer designs or aluminum skin/aluminum honeycomb core sandwich designs. Fiberglass skins are often used in lieu of aluminum skins for aluminum honeycomb core sandwich designs; occassionally, fiberglass (HRP) honeycomb core is used. Adhesive bonding as a part fabrication/assembly method is used extensively in the design of secondary structure parts.

(U) Advance composite secondary structure applications on current aircraft include weapons bay doors, nacelle inlet ramps, structural mode control vanes, avionic access doors, landing gear doors, overwing fairings, and trailing edges (Figure 34).



(U) Figure 34. Current LAD composite applications. (U)

(U) Superplastic-formed/diffusion-bonded titanium secondary structures on current aircraft (Figure 35) include engine access doors, auxiliary power unit doors, and nacelle panel structure.



(U) Figure 35. B-1 production usage (SPF and SPF/DB). (U)

Special-Purpose Structure

(U) The following types of special-purpose structure have been identified for application to strategic aircraft:

1. Laminar flow control surfaces for wing, fuselage, and empennage

2. Boundary layer control for engine air induction systems

3. Nuclear heat pulse - resistance structure

4. Radar absorbant material

5. Laser - Resistant structure

6. Infrared signature reduction structures

(U) A preceding paragraph, "Stealth," addresses the current and projected status of RAM and IR signature reduction structure. The limited state of development of these structures is outlined in the following.

Laminar Flow Control (LFC) Surfaces. (U) The primary interest in LFC has been in the reduction in drag. The use of LFC to reduce drag was not extensively pursued until 1949, when Dr. W. Phenninger began his work at Northrop Aircraft

Company. This work, sponsored by NACA, led to the Air Force program in which Northrop designed, built, and tested the X-21 airplane, which incorporated a full LFC wing (ref 23). Fabrication and flight experience with the X-21A wing demonstrated that the LFC feature can be integrated into an airframe structure with less than 8-percent weight penalty. The average weight per square foot of upper and lower covers and substructure was 9.2 pounds, a reasonable value for its class of airplane. The weights of removable valves, duct connections, and pumping equipment were not included. (U)

(U) The Northrop design employs an outer skin 0.5 to 0.63 mm (0.020 to 0.025 inch) aluminum alloy bonded to an aluminum honeycomb sandwich panel. Slots, 0.152 mm (0.006 inch) in width, are cut in the outer skin in a spanwise direction. These slots connect to 4.8 mm (0.188 inch) plenums, premachined in the adhesive line, which is a minimum of 0.5 mm (0.020 inch) thick. Holes drilled through the honeycomb panel form a passage to channels bonded to the inner surface of the panel. These channels distribute boundary layer air to cross ducts which transfer air to the pumps.

(U) This program has been the most significant full-scale application of LFC concepts to an airplane and probably represents the limit of current technology. LtC J. V. Kitowski summarized the Air Force's position on the technical status as follows:

> "Large areas of laminar flow were obtained at cruise conditions. Full chord laminar flow at high Reynolds number for the low altitude case was obtained. The consequences of wing sweep were determined, and the resulting problem of leading edge contamination was solved. Design criteria were developed for future laminar flow aircraft applications. LFC operation in a real environment was documented. Areas of limited knowledge and achievement may also be identified. The operational practicality and suitability were not demonstrated. Consistency of laminar flow at high Reynolds number was not achieved. Manufacturing cost for a production version of a laminar flow aircraft was not fully determined in this study."

Boundary Layer Control (BLC). (U) BLC has been used extensively during the last 20 years for engine air induction systems at Rockwell. The F-107, XB-70, and B-1 all made extensive use of BLC to minimize flow separation at the inlet boundaries and to control the airflow in the inlet. The structure used to provide the BLC surface consists of porous skin, stabilized by either honeycomb sandwich or stiffeners. The porous panels and duct walls serve as primary load-carrying structure with plenum chambers, inboard of the BLC structure, to collect and distribute the boundary layer air.

(U) The current production method for the honeycomb panels is to bond or braze the face sheets to the core, and then drill small-diameter holes (0.030- to 0.060-inch-diameter) in the mold line surface and larger holes (0.25- to 0.375-inch-diameter) in the back side. For porous, stiffened skin construction, the panels are first milled from thick plate to produce integral stiffeners, and then holes are drilled to the proper diameter between stiffeners. Although both methods are production processes and produce efficient structures, the production costs of fabricating the basic panels and drilling the holes is high.

(U) A promising future BLC panel production technique is becoming feasible through the use of SPF/DB titanium technology. In this technique, the required BLC ducting and slots are concurrently formed with the skin, reducing weight and cost penalties associated with BLC.

Nuclear Heat-Pulse Resistant Structure. (U) Considerable progress has been made on the X-15, XB-70, and B-1 programs to develop structures to resist extremely high, short-time temperature exposure.

(U) Recent tests conducted on titanium truss core sandwich have demonstrated its survivability under simulated nuclear heat pulse. The panels were 1/4-inch thick sine wave truss core fabricated from 6Al-4V titanium. The core was 0.010-inch thick (starting stock), the OML face sheet was 0.014-inch thick, while the IML face sheet was 0.008-inch thick. Prior to testing, the parts were painted on the center mold line only with the B-1 paint system; i.e., one coat MIL-P-23377 epoxy primer and two coats of MIL-C-83286 aliphatic polyurethane topcoat. Each panel was subjected to 10 exposures to simulated nuclear flash. The panel was allowed to cool to 130° F prior to the next flash. Surface temperatures exceeded 2,400° F after each flash. The paint charred on both samples, and there was a slight amount of surface buckling but no structural failure. No cracks or damage to the bonds, face sheet, or core trusses could be found by subsequent metallurgical examinations. Preliminary thermodynamic analyses show that with a 500° F service temperature white paint applied to the external surface of the titanium truss core shell, the outer face sheet maximum temperature will be about 800° F.

Laser-Resistant Structures. (U) The laser threat as a viable weapon is fairly new. As a result, the development of laser-resistant structures is just beginning. Although the results of the new development programs to resist the laser threat are encouraging, the technology is too new to be considered state-of-the-art.

Projected Status - 1995 and Beyond

(U) The advent of advanced metallic and composite fabrication techniques for the structural design of post-1995 aircraft will open new horizons in structural efficiency and fabrication simplicity.

Basic Structure

(U) Primary structure design/fabrication technology should have advanced to the point where large-scale monolithic structures of titanium, aluminum, steel, or metal matrix materials can be used. The designer of post-1995 aircraft will be able to use welding as a primary assembly method to sharply reduce the number of detail parts required. Consequently, post-1995 structure will have a minimum of joints, a minimum of fasteners (skin/substructure penetrations), improved static/fatigue strengths, sharply reduced fuel containment problems, and improved structural efficiency. The designer will have available new and improved alloys in aluminum, steel, and titanium, as well as new and improved metal matrix materials that, when coupled with new manufacturing technologies, will permit the use of large integrally stiffened skins; i.e., built-in spars or conventional stiffeners, large superplastic-formed/diffusion-bonded titanium skins, bulkheads and integral skin and bulkheads; metal matrix reinforced titanium and aluminum structural elements; superplastic-formed aluminum frames and integrally stiffened skins; and large precision net forged or cast aluminum parts.

(U) With advanced composite materials, the designer will be able to use large-scale integral structure concepts for the wing or fuselage. The integral structure wing, for example, would be fabricated by laying up and curing simultaneously one skin and all substructure details, thus eliminating all penetration (fasteners) in the skin and substructure. The other skin will be attached by either fasteners, adhesive bonding, or a combination of both.

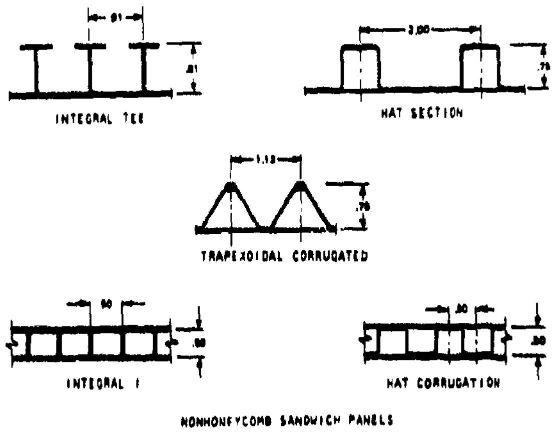
(U) Selected structure technologies that are being developed independently show promise of additional cost and/or weight reduction when combined into hybrid structure. Some of the promising combinations are:

1. Metal covers adhesively and/or mechanically attached to integral advanced composite substructure

2. Composite covers adhesively and/or mechanically attached to superplastic-formed/diffusion-bonded titanium substructure

3. Metal matrix hybrid structure

(U) Secondary sandwich structure and integrally stiffened skins for leading edges, trailing edges, rudders, and fairings will make extensive use of advanced composite skins coupled with advance composite substructure. Typical core and stiffened panel constructions that will be used for future aircraft applications are shown in Figure 36. Where temperature or high-strength requirements dictate the use of metallic secondary structures, the post-1995 aircraft designer will superplastic-formed/diffusion-bonded titanium structures. (U)



(U) Figure 36. Typical core and stiffened panel constructions. (U)

Advanced Composite Technology. (U) The unique advantage of advanced composites in aircraft design results from certain inherent characteristics of this class of material:

1. Very high strength/density ratio
2. Very high modulus/density ratio
3. Tailorable amisotropy
4. Fabrication by layup

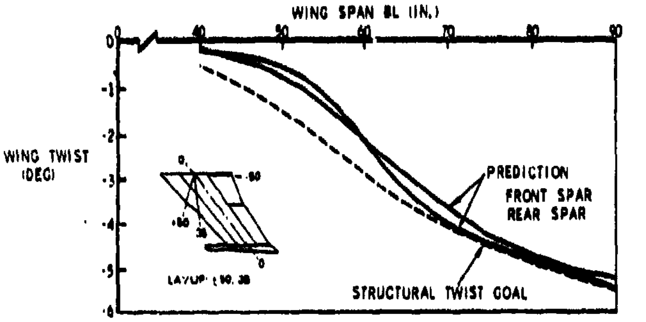
Both the high specific strength and the stiffness make possible a significant degree of weight saving, but the highly orthotropic nature of composite laminate and the ability to fabricate large segments of an airframe with oriented laminates magnify the weight savings.

(U) Aeroelastic tailoring (AT) consists of the systematic arrangement of component geometries and composite ply orientations for improvement of the aerodynamic properties of wings, the enhancement of aeroelastic effectiveness of the airframe, and compliance or reduction of weight and mass distribution.

(U) The graphite/epoxy composites that will be used in the wing/fuselage are ideally suited for AT, lending themselves to tailoring in at least two ways:

1. Tailored local angle of attack (Figure 37)

2. Tailored camber



	GR/EP			BORON		TOTAL NO. OF PLIES
PLY	+30	-30	35	0	90	
ROOT	16 (30)	14 (26)	6 (11)	14 (26)	4 (7)	54 (100%)
TIP	6 (37.5)	6 (37.5)	4 (25)			16 (100%)

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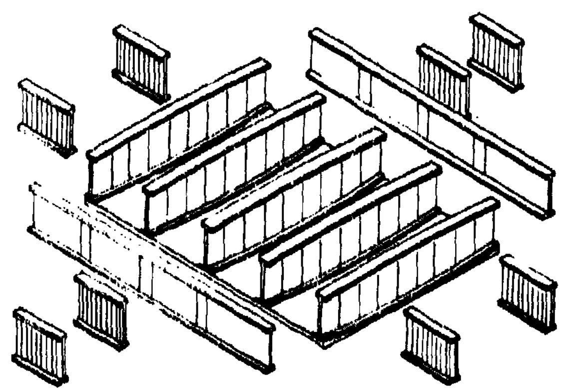
(U) Figure 37. HiMAT aeroelastic tailoring accomplishment. (U)

Both methods increase lift for a given drag, or conversely, decrease drag for a given lift. Thus, AT payoff lies in affording a reduced engine size, which, in turn, decreases the structural weight, resulting in increased maneuverability and handling. These combined increments in system effectiveness, which were directly derived from judicious tailoring, will be translated into a significant cost-effective improvement of the weapon system.

(U) Preliminary analytical studies show that aeroelastic tailoring of advanced composites can also be used to overcome aeroelastic divergence in forward-swept wings with little or no weight penalty. Recent aerodynamic studies indicate that aircraft with forward-swept wings have benefits in high speeds such as drag reduction, minimum aerodynamic center shift in the transonic regime, and improved stability. However, the weight penalties incurred to overcome aeroelastic divergence have limited forward-swept wing developments to very small forward sweep angles. This aeroelastic phenomena occurs at speeds where the aerodynamic loading exceeds the elastic restoring forces of the wing structure, thus causing an increase in angle of attack, which, in turn, causes an increase in the aerodynamic loading. This instability results in catastrophic loss of the wing.

(U) Since the interaction between aerodynamic loading and aeroelastic tailoring is crucial to the advancement of forward-swept wing technology, the Air Force is funding programs to confirm the analytical predictions by wind tunnel testing of subscale models. Future Air Force plans include full-scale flight demonstration of this technology, which will allow it to be considered state-of-the-art prior to 1995.

(U) In addition to weight savings and aeroelastic tailoring advantages, these materials present the opportunity for reducing manufacturing costs and life cycle costs. Owing to the processability and moldability of advanced composite materials, large major assemblies, such as the intermediate fuselage, vertical stabilizer torque box assemblies, and wing torque box assemblies, may be molded and cured in one processing operation. This is accomplished by laying up prepreg tape, cutting to net mold size, forming and staging integral subassemblies, and placing the subassemblies into a final assembly female curing fixture. The final assembly is then cured in one operation to yield a finished net-size integral structure (Figures 38 and 39).



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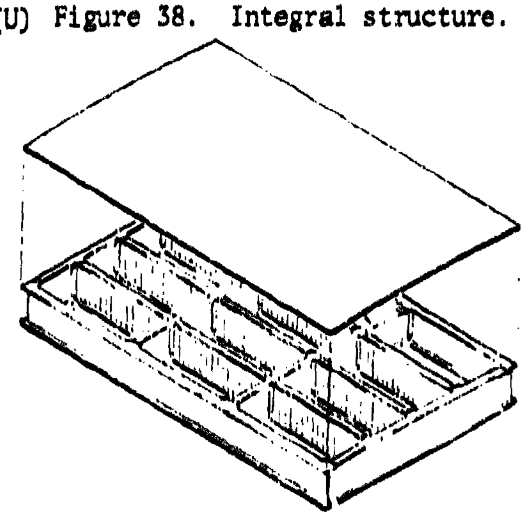
(U) Figure 38. Integral structure. (U)



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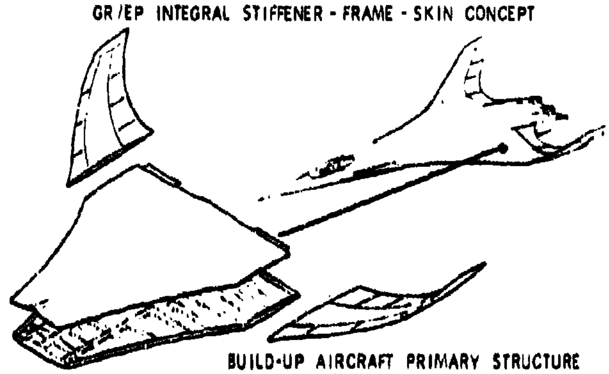
(U) Figure 39. Multispar cocured integral structure. (U)

(U) The wing torque box is especially suited for advanced composite integral structure. The lower cover, spars, and ribs would be cocured into one large assembly, with the upper cover either bolted or bonded in place (Figure 40). The integral structure lends itself well to integral fuel tanks, virtually eliminating fuel leakage problems. Access holes into the wing should be through the front and rear spars, with limited access through the upper cover.



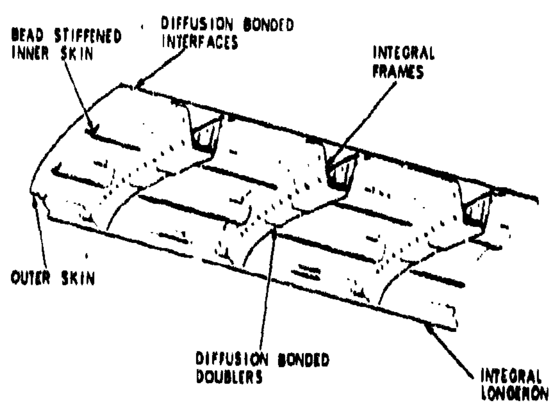
(U) Figure 40. Integral structure concept. (U)

(U) The forward fuselage section is suited to the application of large contoured advanced composite skins fabricated with cocured integral stiffeners and frames. The integrally stiffened skins would then be attached by conventional methods to precision net cast aluminum bulkhead or SPF/DB titanium bulkheads, depending on load/temperature requirements.

(U) The rudders, trailing edges, and contour surfaces (fairings) of the post-1995 strategic aircraft lend themselves well to advance composite skin sandwich structure. The structure core material would be advance composite or reinforced low-density foam to reduce or eliminate the sandwich structure core corrosion problems of current aircraft.

Titanium Technology. (') Improved welding methods, such as plasma arc welding, coupled with superplasti. forming and diffusion bonding technology, offer a manufacturing scheme for production of metal aircraft structures. Titanium structures will be molded to configuration and integrally bonded in one process that will replace today's large subassemblies and myraid detail/fastener problems. These integral metal structures may then be joined by improved automatic welding methods into major assemblies. Weight and cost reductions will be gained by reducing the number of details in the integral structure and by eliminating fasteners and seam overlaps on major assemblies. Elimination of environmental and fuel sealing problems will further reduce manufacturing and maintenance costs. (U)

(U) Structure on the post-1995 aircraft where superplastic-formed/diffusion-bonded (SPF/DB) titanium applications appear extremely attractive are the aft fuselage section, leading edges, canard, inlet duct (nacelle) structure, and highly loaded doors; i.e., landing gear, engine access, and weapons bay doors. The aft fuselage strength/temperature requirements due to anticipated engine placement make this structure viable for SPF/DB titanium application. Full complete stiffened skins, such as portrayed in Figure 41, will be superplastic formed and diffusion bonded in one operation. Also, full fuselage frames and bulkheads (Figure 42) with thin webs will be formed by the same process. Assembly of stiffened skins and frames will be accomplished by advanced welding methods. Compound contoured structure such as leading edges in high FOD areas are natural candidates for SPF/DB titanium applications and will be considered for post-1995 strategic aircraft.



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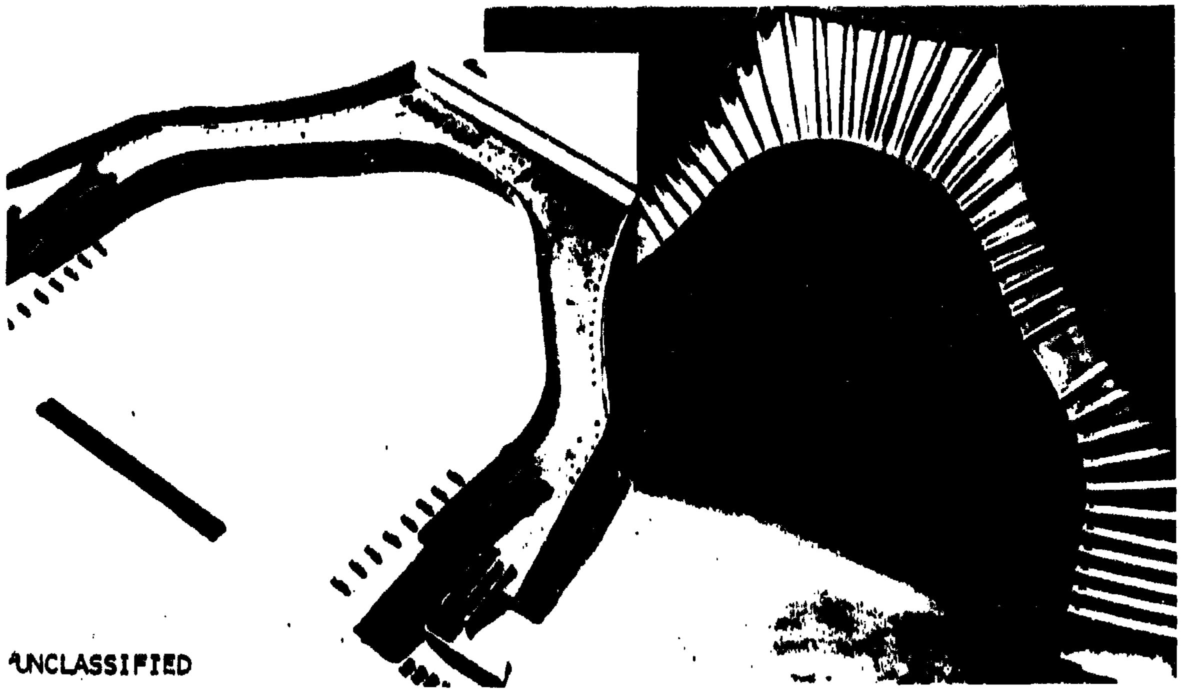
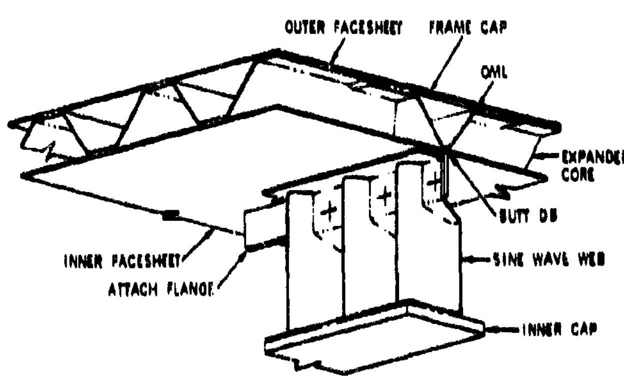
(U) Figure 41. Fuselage-type structure using SPF/DB with integral formed frames. (U)



(U) Figure 42. Nacelle frame comparison. (U)

(U) A highly loaded area like the wing carry-through section lends itself well to titanium diffusion bonding. By this method, fasteners can be eliminated in areas where there is little space available and where the structure is subjected to high loads (Figure 43). The complete part could be bonded and only adjacent structure mechanically attached.



(U) Figure 43. Typical wing/fuselage structure using SPF/DB process. (U)

Steel Technology. (U) Many structural parts in high-load areas of post-1995 strategic aircraft will use high-strength/low-cost steel rather than titanium or aluminum. This predicted use is based on current ongoing development technology programs for AF1410 steel (14Co-10Ni). Studies show that where its strength can be used efficiently, cost savings of 30 percent and weight savings of 10 percent are achievable when compared with titanium in the same application. Where volume is critical, reduction in part size is also possible. An attractive feature of this steel alloy is that it can be welded without serious strength penalty or special vacuum provisions, making it feasible for large assemblies where welding is the primary assembly method. (U)

(U) Areas of the post-1995 strategic aircraft which could effectively use this steel alloy are:

1. Landing gear
2. Wing pivots
3. Wing carry-through
4. Empennage root attachments
5. Weapons hard points
6. Wing root ribs
7. Empennage spindle fittings

Applications such as the landing gear structure and spindle fittings are especially attractive due to the forgeability and high fracture toughness qualities of this steel alloy.

Aluminum Technology. (U) Fuselage structural components that react concentrated loads, such as bulkheads that provide landing gear or stores support, appear attractive for large, net, precision cast details. Fuselage structure that forms the boundary of pressurized compartments such as crew compartment, avionics compartments, and fuel tanks could be made of integrally stiffened superplastic-formed skins assembled into panel assemblies and joined to adjacent structure by adhesive bonding, weld bonding, or with mechanical fasteners. Aluminum fittings that are sized by fatigue, crack growth, fracture toughness, and/or stress corrosion requirements will be made out of dispersion-strengthened aluminum products. Development of the arc seam welding process for joining thin-gage aluminum assemblies will extent the application of aluminum to areas where titanium is presently used.

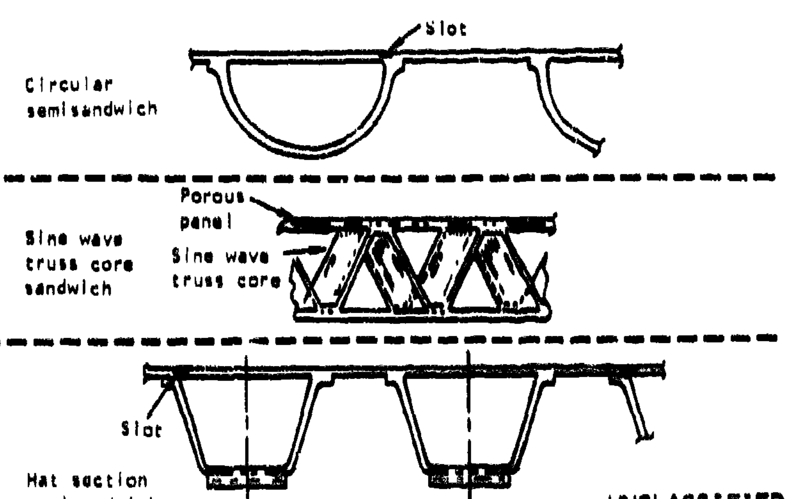
Metal Matrix Technology. (U) The anticipated operating environment of the post-1995 strategic aircraft (bomber) is not sufficiently stringent in terms of operating temperature to warrant the extensive use of metal matrix materials. Use of these materials should remain an open option until aircraft temperature and loadings are better defined and future cost/weight/performance trades for the vehicle are completed.

Potential metal matrix options for the aircraft could include:

1. Landing gear - B/Al tube structure with integral wear liner
2. Longerons - SiC/Al, diffusion-bonded or cast
3. Engine hot-box structure - beryllium/titanium extrusions
4. Ramp structure - diffusion-bonded B/Ti or SiC/Ti
5. Forward and intermediate fuselage - SiC/Al castings fuselage bulkheads
6. Canard surfaces - diffusion-bonded B/Al or SiC/Al

Special-Purpose Structure

Laminar Flow Control (LFC) Structure. (U) The development of the SPF/DM titanium process has presented new possibilities for LFC. Structural arrangements, similar to those shown in Figure 44, which have been produced on a laboratory scale, will be scaled up to full-scale production aircraft by 1995. These concepts offer highly efficient structures which can perform the LFC function with virtually no weight or cost penalty over non-LFC panels.



(U) Figure 44. Selected LFC panel concepts. (U)

Boundary Layer Control Structure. (U) The major advance in BLC structures will be in improved methods of producing existing concepts. Using preperforated or slotted skins in the SPF/DB cycle, BLC titanium panels will be fabricated at significantly lower cost than at present. For applications where integrally stiffened aluminum BLC panels are desired, new drilling methods will substantially reduce the manufacturing costs. Both electron beam and laser drilling, which are rapidly approaching production capabilities, will be fully matured by 1995.

Nuclear Heat-Pulse Resistant Structures. (U) The only types of structure for which hardening methods against the nuclear heat pulse do not presently exist are transparencies and radomes. However, replacement of existing organic transparent materials with glass, coupled with predicted improvements in interlayers, should provide adequate windshields and canopies in the 1995 period. For radomes, two solutions appear promising. Ceramic radomes, already produced experimentally, offer an immediate solution which requires only scale-up to production. A substantial weight penalty would result, however. The emerging development of multilayer, reactive array radomes offers a good possibility of providing a nuclear heat-pulse-resistant structure.

Laser-Resistant Structures. (U) The rapid progress in laser weapons has spurred a number of programs to develop laser-hardened structure. Programs recently completed show that metallic skins can be hardened in two ways:

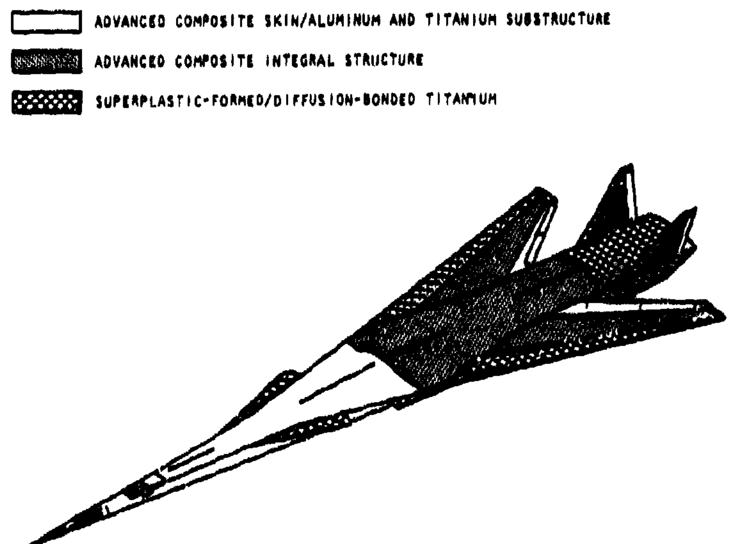
1. Reflective Outer Surface - On aluminum skins, this can be accomplished by polishing the outer surface. Titanium requires a coating of polished aluminum or copper to provide the required reflectance. The exterior finish can be applied to the polished surface without affecting its laser resistance.

2. Heavy-Gage Outer Skins - Skin thickness in aluminum or titanium in excess of 0.25 inch will serve as a heat sink to prevent penetration by most laser weapons.

(U) Advanced composites present more of a problem to harden. Studies underway indicate that coatings can provide some protection, but heavy-gage material. appears to be the best solution. For transparencies, new materials have been developed which will defeat the laser threat. With sufficient emphasis, these materials could be available on a production basis by 1995.

Structural/Manufacturing Technology

(U) The primary structural portions of the aircraft (i.e., wing, empennage, and fuselage sections) will be designed and fabricated using an integral structure concept. A tentative/generalized post-1995 strategic aircraft using innovative integral structure concepts and post-1995 materials is portrayed in Figure 45. (U)



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(U) Figure 45. Integral structure concept use in advanced strategic aircraft. (U)

(U) The post-1995 strategic aircraft will be assembled by innovative methods to sharply reduce manufacturing costs as compared with the conventional assembly methods of the current period. Skin and stringer mechanically fastened structure will be supplanted by integral structure concepts that reduce or eliminate many of the problems inherent in current design/assembly methodology; specifically, the excessive number of mechanical joints, drilled holes, fasteners, and fuel tank (wet structure) sealing problems that drive up the cost of current aircraft.

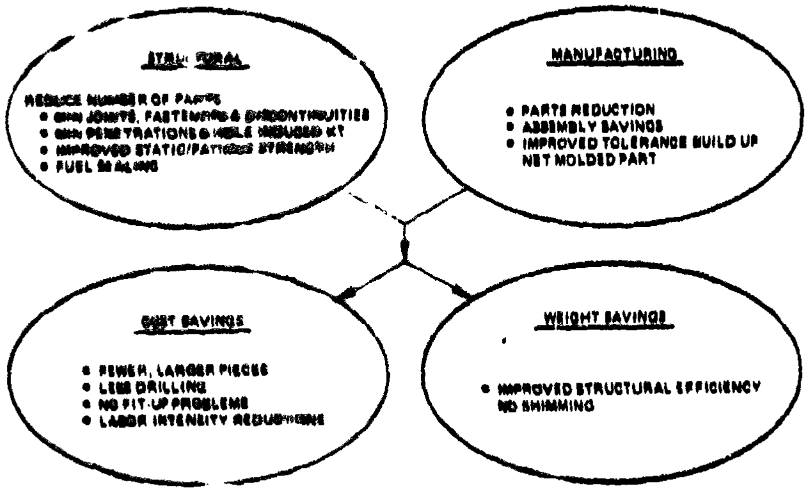
(U) Structure fabricated by the integral structure concept, whether molded/bonded advance composite integral structure or SPF/DB titanium structure, offers the promise of increased reliability coupled with lower field maintainability problems while simultaneously enhancing performance and reducing acquisition costs.

(U) Developing welding methodology as a primary assembly technology for large monolithic aluminum and titanium structures will open new vistas in aircraft design and construction, and will permit the integral structure concepts and payoffs to be extended to major primary structure, such as aft fuselage sections for titanium or forward fuselage sections for aluminum.

(U) Application of SPF/DB titanium technology or metal matrix technology to secondary structure such as leading edges and doors will minimize damage due to ground handling and FOD, while being cost/weight competitive with the conventional aluminum structure of today's aircraft. A summary of manufacturing technology anticipated for the post-1995 time frame is presented in Table 8, for advance composites, and in Table 9, for metals.

Computer-Aided Design and Computer-Aided Manufacturing (CAD-CAM). (U) With the extension of present computing equipment and capabilities to the 1995 time frame, based on advances made in the past 20 years, it is logical to expect larger and more complex systems to produce design data at a fraction of today's cost. Reduced design time based on individual designer terminals will be expected. Drawing development will use interacting graphical techniques to determine optimum designs for all functional systems. The data base thus obtained will be used in producing the parts through totally numerically controlled machining and fabrication equipment.

Improved Technology Payoffs. (U) Improved technology will show payoffs in the form of decreased aircraft weight and cost in the 1995 era due to design innovation and improved manufacturing technology. One key to achieving sharply reduced costs will be the large-scale use of integral primary structure for the wing, fuselage, and empennage. The benefits that will accrue from the use of primary integral structure are shown in Figure 46.



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(U) Figure 46. Integral primary structure program benefits. (U)

(U) TABLE 8. 1995 TECHNOLOGY - MANUFACTURING TECHNIQUES FOR ADVANCED COMPOSITES (U)

Layup of laminates directly on curing molds by use of high-speed automated tape laying machines.
Molding and curing of large integral structural assemblies in one operation.
Automatic flow detection and prevention in automated curing processors.
Elimination of holes and fasteners in joints by bonding with new high-strength, high-temperature adhesives.
Replacement of aluminum honeycomb cores by high-strength, high-temperature foams simultaneously molded, cured, and internally reinforced with high-strength dindritic graphite forms or nonhoneycomb advance composite core forms.
3-D fabricating machines that produce laminated structures with desired triaxial loadcarrying capability.
Environmental protective coatings of metallic films deposited on exterior surfaces.
High-speed laser cutting of tape and laminate layups.

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(U) TABLE 9. 1995 TECHNOLOGY - MANUFACTURING TECHNIQUES FOR 1995 AIRCRAFT (U)

Automated machining and drilling coupled to CAD-CAM systems.
Larger precision net castings and forgings.
Superplastic forming and diffusion bonding of integral structures in one operation.
Reduction of fasteners by use of automated welding machines for joining large assemblies.
Use of metal matrix for reinforced composite structures.
Use of welding as a primary assembly method.

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(U) Cost and weight trade studies for application of titanium DB and SPF/DB structural applications to an advanced aircraft on a replacement basis (no resizing of existing designed structure) indicate the following payoffs could be achieved:

1. 23% cost savings - integral structure forward fuselage
2. 63% cost savings - integral structure aft fuselage
3. 51% cost savings - integral structure wing (expanded sandwich - truss core design)
4. 10% weight savings - airframe structural weight
5. 5.4% useful load increase
6. 2.9% weight savings - takeoff gross vehicle weight

(U) Based on NASA-CR-145111, "Evaluation of Low Cost Titanium Structure for an Advanced Aircraft," it is reasonable to predict that integral structure titanium applications to a post-1995 strategic aircraft initiating with the initial design phase should reduce vehicle cost by 50 percent and weight by 30 percent.

(U) Advanced composite integral primary structure trade studies (NA-77-264L, "Technical Proposal for Wing/Fuselage Critical Component Development Program Preliminary Structural Design") indicate that if advanced composite integral structure was introduced in the initial design phase, cost savings of 33 percent could be realized against conventional metal structure, with a corresponding predicted weight savings of 33 percent.

(U) Preliminary trade studies, comparing a theoretical design using silicon carbide, continuous, filament-reinforced cast aluminum matrix structure with conventional production sheet metal construction, indicate cost reduction approaching 70 percent, for production quantities of 200 units, with a corresponding weight reduction of 28 percent. A comparison of man-hours of effort per pound of structure indicates this type of construction shows remarkable potential for furthering the cost savings already demonstrated by epoxy matrix composites.

(U) Though not as dramatic, a substantial weight savings of some 30 percent or more can be shown by DB sheet monocoque structure employing advanced welding and DB techniques to eliminate many of the fasteners and their related installation operations. This type of construction has been traded in fuselage and wing structure to show a concurrent 25-percent per unit, or greater, production cost savings.

Reliability/Maintainability. (U) The post-1995 strategic aircraft by virtue of the incorporation of advanced welding techniques and integral structure concepts for fuel containing areas of the structure will have enhanced maintainability characteristics by elimination/reduction of fasteners, joints, and fuel leakage problems.

(U) Application of SPF/DB titanium structure to leading edges and doors exposed to FOD will result in minimized field maintenance activity in contrast to today's aircraft. Development of advanced composite core details skin sandwich structure will eliminate core corrosion problems currently prevalent with aluminum, such as honeycomb structure.

(U) In general, it can be predicted that the application of the innovative manufacturing technologies discussed in the preceding paragraphs will bring about a significant improvement in the maintainability characteristics of post-1995 strategic aircraft.

(U) The long-term service life of post-1995 aircraft will place additional emphasis on the reliability of materials selected for airframe structure. Based on current technology development programs and development programs supporting new materials, damage tolerance, crack growth, flaw growth, and fatigue characteristics, enhanced by characterization in environments which simulate the operational envelope, should be sufficiently defined to permit the aircraft designer to freely choose from among the materials discussed in the paragraphs on materials and materials technology.

(U) Repair technology for post-1995 aircraft is dependent upon keeping pace with innovations in material technology. Recent history suggests that this normally does not occur, and often the material combinations with most significant performance/cost benefits are delayed in application to production aircraft. The material selections developed for post-1995 aircraft as a result of this study should have corresponding technology developments in repairability during the pre-1995 time period.

(U) Some configuration features incorporated in the ISADS study to improve reliability/maintainability are shown in Figure 47.

(U) The projected availability dates for these structures and materials technologies are summarized as Figure 48.

- MODULAR STRUCTURE/SUBSYSTEM FEATURES
- QUICK ACCESS FOR COMPONENT REPLACEMENT
- LEFT/RIGHT INTERCHANGEABLE ITEMS
  - CONTROL SURFACES
  - LANDING GEAR
  - TRANSPARENCIES
  - ENGINES
  - WING & CANARD BOXES
- RAPID DAMAGE REPAIR FEATURES
  - QUICK DISCONNECT MODULES

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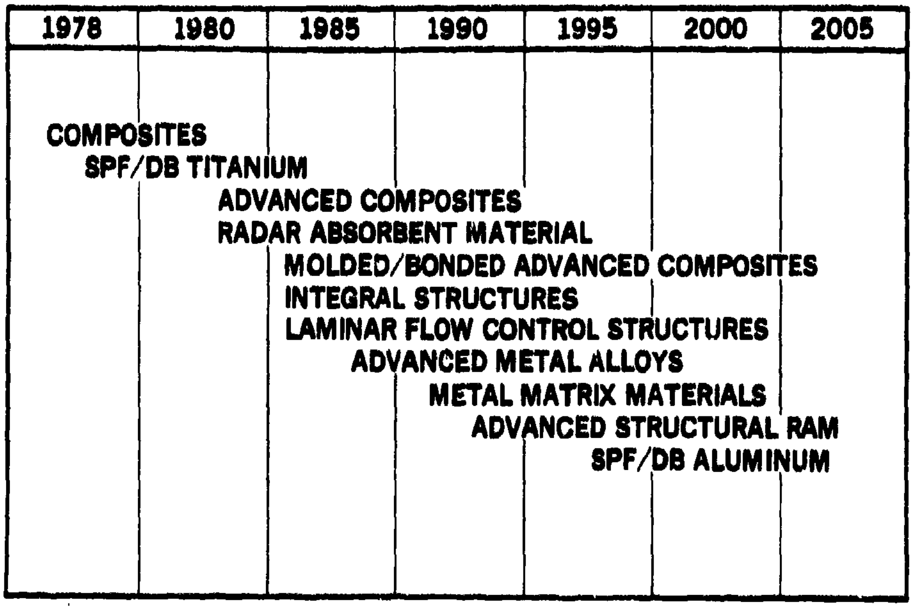
(U) Figure 47. Reliability/maintainability. (U)



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(U) Figure 48. Structures/materials technology projections. (U)

Section III

CONCEPT INTEGRATION AND TRADE STUDIES

INTRODUCTION

(U) In Tasks II and III of the ISADS study, the selected advanced technologies of Task I were incorporated into strategic aircraft conceptual sketches. These sketches were subjected to a filtering process to select one base line concept for each catagory, defined as follows:

1. Low-cost simplistic
2. Minimum weight
3. Minimum penetration time
4. Stealthy
5. Laser defense

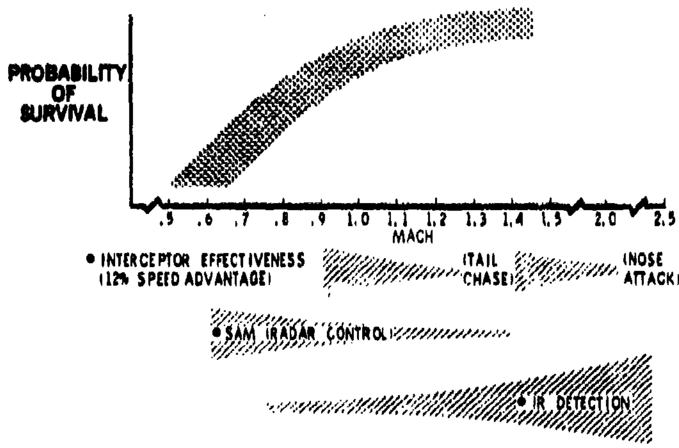
The five baselines were then sized and subjected to a series of configurational and technological trade studies.

ISADS DESIGN GROUND RULES

(U) Concept integration began with the list of technologies identified in Task I and the ground rules of the ISADS study. These ground rules were either defined in the Statement of Work or assumed by the contractor in cooperation with the Air Force ISADS program manager, and are described in the following paragraphs.

(U) The prime mission of the ISADS aircraft was defined in Statement of Work to be a 5,250-nautical-mile unrefueled "high-low strategic penetration mission (Figure 5). Other fallout missio he a theater mission and a standoff, loiter-type mission (Figure 6)

(S) The exact mission mach numbers were left to the cont. Rockwell drew upon its B-1 data base to selecte penetration mach num or best compromise probability of survival. Figure 49 summarizes the probability of survival trend for a manned bomber penetrating Soviet airspace at 200-foot altitude. The four hashed triangles at the bottom depict the effectiveness of the primary threats as a function of mach number. The broad curve at the top summarizes the overall probability of survival. It can be seen that the knee of the curve occurs at mach 1.2. This was selected as the penetration mach number of the minimum penetration time configuration. For the subsonic concepts, mach 0.72 was selected, since that is the onset speed for infrared detection due to aerodynamic heating, as shown in the bottom hashed triangle.(S)



(U) Figure 49. Survivability trends. (U)

(U) Penetration withdrawal speed was selected as mach 0.55, based on B-1 experience. The cruise legs were initially selected to be at mach 0.70, best altitude, but the subsequent sizing effort indicated higher cruise speeds would reduce takeoff weight.

(U) Payload was defined in the Statement of Work to be 50,000 pounds, consisting of 16 advanced air-launched cruise missiles on two rotary launchers, or alternate conventional stores.

(U) Ride quality and flight control criteria were established in the Statement of Work by referring to AFFDL TR-73-135, "Terrain Following Criteria," and nuclear hardening design criteria were defined as follows:

1. Two psi plus gust at sea level

2. Thermal free field of 80 cal/sq km (requires three sequential applications in this environment)

3. Withstand electromagnetic pulse environment

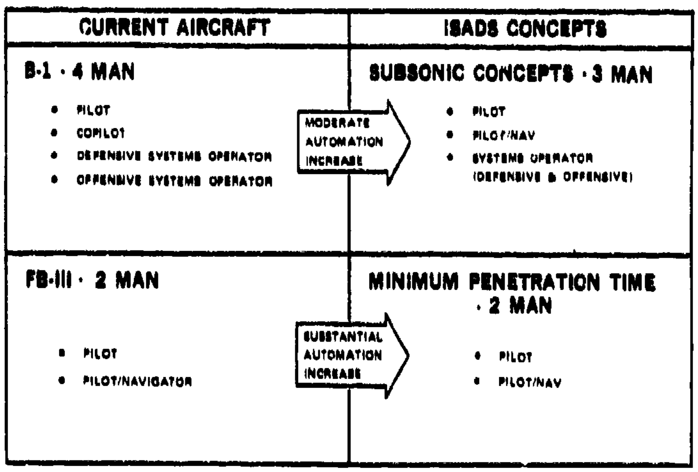
4. Survivable fuel and flight control system

(U) The Statement of Work gave freedom to the contractor in defining other ground rule assumptions necessary to restrain the ISADS study scope. These were made in cooperation with the Air Force ISADS program manager and are described in the following paragraphs.

(U) While the Statement of Work stated that the ISADS aircraft were to be "designed to meet postulated requirements of the post 1995 time period," no firm guide to establish a specific dateline was given. It was therefore assumed that these aircraft would have a 1995 initial operational capability (IOC) date, from which production dates, RDT&E start dates, and technology readiness dates could be established. On the B-1 program, the IOC date corresponded schedule-wise with production of the 65th aircraft; therefore, this was assumed for the ISADS study. The major effect of these assumptions is that it limits the usable advanced technologies to those which will be available by approximately 1985, when RDT&E must begin.

(U) Subsystems definition is beyond the scope of this study, but their weight, volume, and placement have a major configurational impact. With no avionics requirements given, Rockwell assumed a 1995 technology, B-1 equivalent capability avionic system. This assumption proved to be a major driver in weight, cost, and aircraft geometry due to the high degree of sophistication of the B-1 avionics. Similarly, B-1 equivalent assumptions were made for landing gear, APU, and other subsystems.

(U) To define crew size, it was assumed that the current phenomenal advances in computing technology will allow most routine crew functions to be automated. This should allow the B-1 crew complement of four to be reduced to three (Figure 50). For the low-level supersonic penetrator (minimum penetration time), the high degree of automated flight control which will be required will allow a crew of two.



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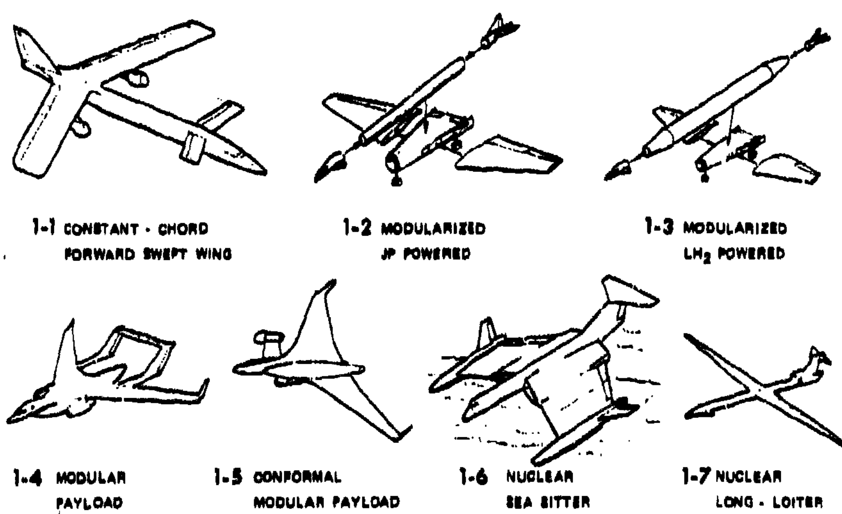
(U) Figure 50. Crew size. (U)

BASELINE SELECTION

(U) Baseline concept selection was accomplished as a three-step screening process, (Figure 4). Initially, technologies were combined to produce six to eight conceptual sketches oriented toward each of the five aircraft categories under consideration. A qualitative assessment reduced the number of concepts to be considered to two or three concepts per category. A more detailed preliminary analysis was then applied to the remaining concepts to select the most viable concept in each category. This airplane was then subjected to a highly detailed computerized analysis to calculate performance and resize the vehicle, as necessary, to meet performance requirements.

CONCEPTUAL SKETCH DESCRIPTIONS

(U) Six to eight candidate concepts were sketched for each of the five required aircraft categories. These candidates were intended to be imaginative and innovative and to include as many high-impact technologies as feasible. For each vehicle, a list of incorporated technology features was also prepared.



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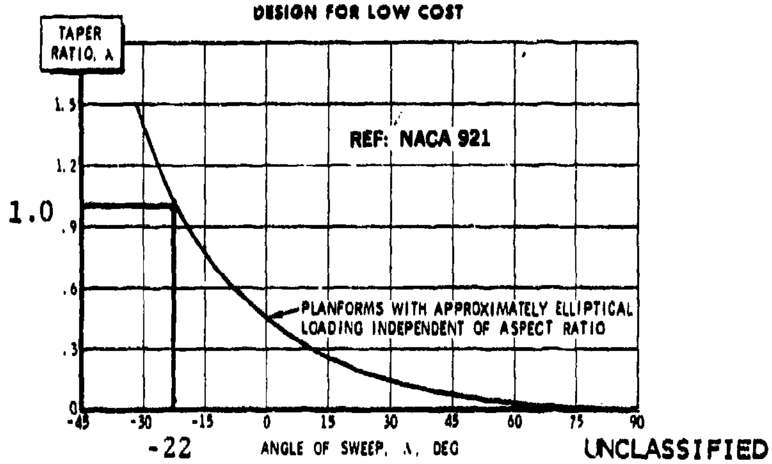
(U) Figure 51. Low-cost simplistic concepts (U)

(U) Figure 51 shows the seven conceptual sketches intended to fit the category of "low-cost simplistic."

(U) Concept 1-1 is a simplistic structure concept. Its major feature is the constant-chord forward-swept wing. As is evident in general aviation, the constant-chord wing is the cheapest and easiest to build, but usually has excessive drag. However, as Figure 52 shows, a forward sweep of 22 degrees will produce an elliptical lift distribution, which gives minimum induced drag. This is applicable only in light of recent work on the forward-swept wing concept, in which proper biasing of the composite wing box plies has been shown to eliminate aeroelastic divergence at a negligible weight penalty. Thus, a constant-chord forward-swept wing with no weight or aerodynamic penalty and with all the production and maintainence advantages of a constant-chord wing can be built. (U)



(U) Figure 52. Effect of sweep on desired taper ratio. (U)

(U) Concept 1-1 also features the canard/tandem-wing concept, in which an oversized canard carries a large percentage (30 percent) of the aircraft weight. This provides a bridge-type support for the fuselage, minimizing its weight while providing a broad range in allowable center of gravity.

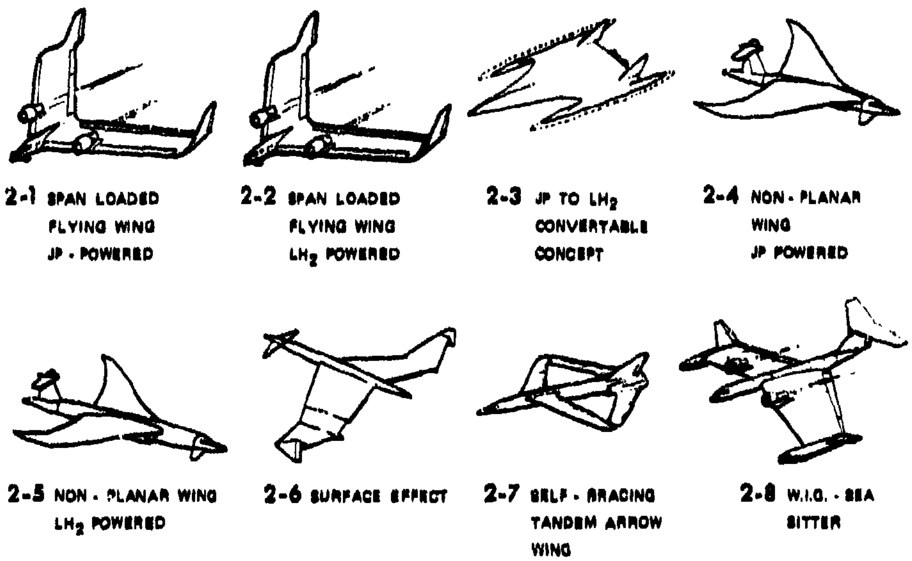
(U) Concepts 1-2 and 1-3 are the same aircraft, which is modularized to allow conversion from JP fuel to liquid hydrogen, when it becomes practical. The concept features a simplistic airframe with straight taper wings and a circular cross-section fuselage. A pod carries propulsion, landing gear, payload, and subsystems.

(U) Concept 1-4 features a modular payload pod, allowing the basic airframe to be used as a strategic bomber, tanker, cargo, or other aircraft type, by replacing the payload pod. The concept features winglets, a blended wing-body, and a boom-type tail support to reduce pod interference for the tanker version. The cost savings is expected to occur by increasing the total aircraft buy, hence, reducing unit fixed costs.

(U) Concept 1-5 is similar to concept 1-4. Changes include deletion of the tail booms to minimize wetted area, addition of a canard for trim, and location of the engines at the tips of the canards to increase field of view of antennas in the AWACS version of the payload pod. Also, the underside of the fuselage is shaped to minimize the interference drag of the pod.

(U) Concept 1-6 is a nuclear sea sitter which would remain indefinitely on station. This would reduce the number required for a given effectiveness. Nuclear power would enable penetration at the enemy's weakest point by circumnavigating his borders.

(U) Concept 1-7 is a nuclear long loiter which would loiter indefinately on station, with the same result as for concept 1-6.



(U) Figure 53. Minimum weight concepts. (U)

(U) Figure 53 shows the eight concepts of the minimum weight category.

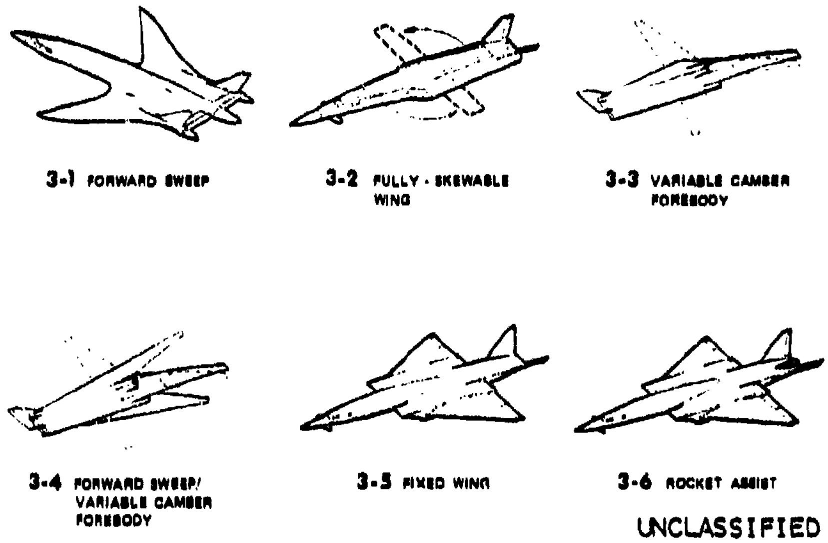
(U) Concept 2-1 and 2-2 are span-loaded flying wings. Here the fuel and payload are distributed along the wing, reducing the structural weight. Winglets reduce the drag penalty associated with aft-swept, constant-chord wings. Concept 2-1 is JP-powered; whereas concept 2-2 is liquid-hydrogen-powered and, hence, features a thicker wing to contain the bulkier fuel.

(U) Concept 2-3 is a highly blended, thin delta wing with all fuel contained in tip tanks. These tanks can be interchanged with larger, cryogenic tanks for eventual conversion to liquid hydrogen.

(U) Concepts 2-4 and 2-5 are the same aircraft, again JP to LH_2 convertible via plugging the fuselage. A nonplanar wing is used to minimize induced drag, and a canard trimmer is used to minimize trim drag.

(U) Concept 2-6 is a ground-based surface effects aircraft, as opposed to a similar concept, 2-8, which is water-based. Both use ground effect to minimize drag during cruise and have power enough to climb up to clear obstacles.

(U) Concept 2-7 seeks to use the structural concept of the self-bracing tandem arrow wing, in which fore- and aft-swept arrow wings meet at the tip, providing triangular bracing.



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(U) Figure 54. Minimum penetration time concepts. (U)

(U) Figure 54 shows the six concepts in the minimum penetration time category.

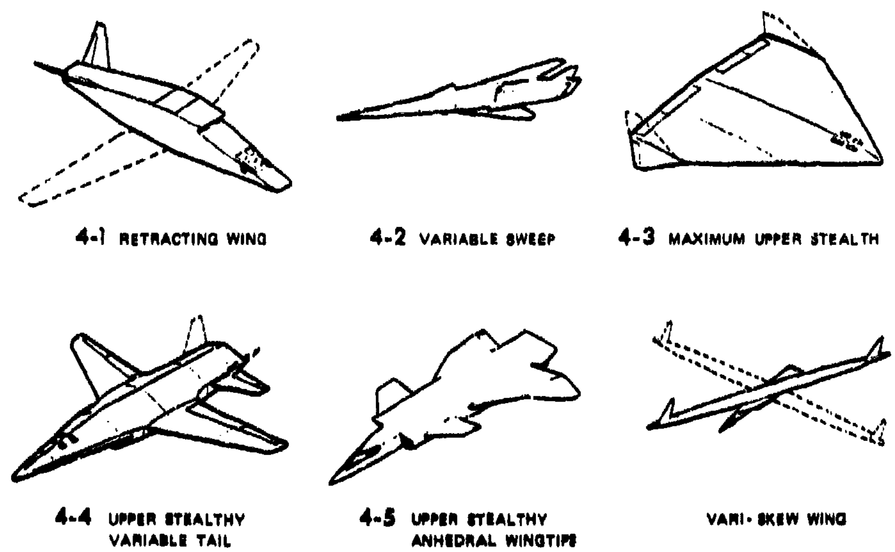
(U) Concept 3-1 uses the forward sweep concept to reduce wave drag. Two-dimensional nozzles provide pitch and roll control.

(U) Concept 3-2 uses a fully skewable, variable-skew wing. At high dynamic pressures, most of the drag is strictly due to skin friction. By fully skewing the wing, the skin wetted area can be minimized and, hence, the friction minimized. Intermediate skew positions provide good transonic cruise, while unskewing the wing provides high lift for landing.

(U) Concept 3-3 uses a fully sweepable wing, for the same reasons. A variable camber forebody provides pitch trim when the wing is fully swept.

(U) Concept 3-4 is identical to 3-3 except that the wing is a variable-sweep, forward-swept wing.

(U) Concepts 3-5 and 3-6 are both low-risk concepts featuring fixed delta wings and circular-section fuselages. Forward-located 2-D vectorable nozzles allow supercirculation lift for takeoff and landing. Concept 3-6 features rocket-assisted takeoff.



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(U) Figure 55. Stealth concepts. (U)

(U) Figure 55 shows the six conceptual sketches to fit the stealthy category.

(U) Concept 4-1 uses stealth technologies developed under Rockwell's Surprise Fighter program. Radar tests of a model of this shape showed virtually no radar return from most directions. The aircraft penetrates at high mach number with its wings fully stowed, leaving only a slab-sided shape with minimal intersections.

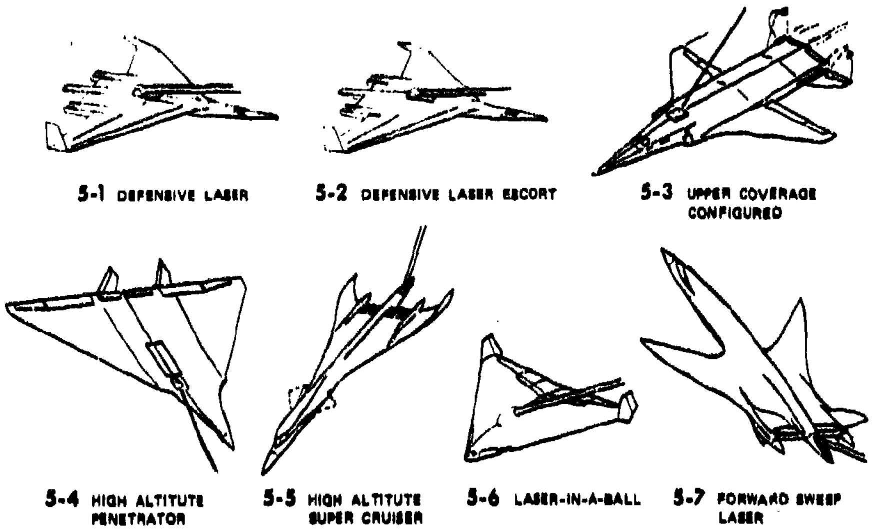
(U) Concept 4-2 uses a flat top to minimize return from above. Inlets are hidden below the wing, which is variable sweep.

(U) Concept 4-3 is a flat-topped, flying delta wing. All signature-producing features such as inlets, nozzles, and tail surfaces are hidden below the wing. The vertical tails are shown on rotary actuators to rotate up for landing, although this later proved unneccesary.

(U) Concept 4-4 is a fairly straightforward concept featuring slab sides and a hidden inlet. Again, the vertical tails rotate from lower to upper for landing.

(U) Concept 4-5 is a slab-sided canard layout which uses anhedral wingtips for a stealthy vertical surface. Long curved ducts obscure the engine face.

(U) Concept 4-6 uses a variable-skew wing to minimize the frontal area, which tends to reduce forward aspect radar and visual signature.



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(U) Figure 56. Defensive laser concepts. (U)

(U) Figure 56 shows the conceptual sketches in the defensive laser category.

(U) Concept 5-1 is a tailless aircraft which uses vectorable 2-D nozzles for longitudinal trim. Winglets reduce induced drag, and a pop-through turret provides 360-degree coverage.

(U) Concept 5-2 is a scaled down version of 5-1 which carries no payload. It is to serve as an escort to other bombers.

(U) Concept 5-3 features a single top-mounted turret which, because of the aircraft shape, can cover the whole upper hemisphere plus 5 to 15 degrees downward. Fold-down tails eliminate rearward blocking.

(U) Concept 5-4 is a high-altitude subsonic penetrator with a lower mounted turret. The flat bottom provides look-up stealth.

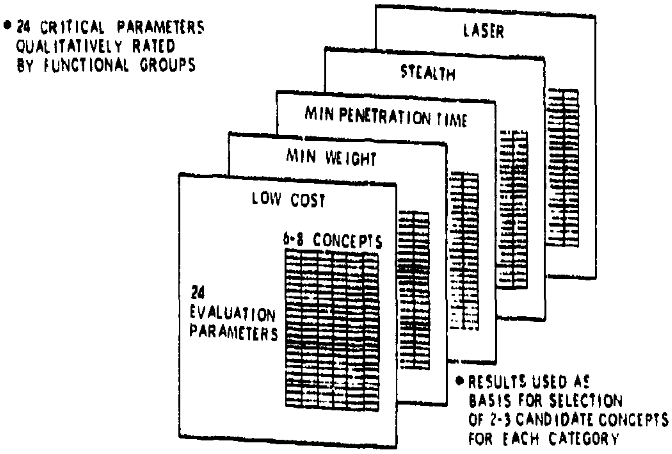
(U) Concept 5-5 is a high-altitude supersonic cruise penetrator with a rear hemisphere coverage laser. A retracting canard minimizes supersonic trim drag.

(U) Concept 5-6 is a flying wing using the "laser-in-a-ball" concept, in which all components of the laser are continued in an aimable, removable ball turret. This provides upper and lower spherical coverage.

(U) Concept 5-7 is a forward-swept wing configuration. The laser is contained in a rear stinger, providing aft-hemisphere coverage.

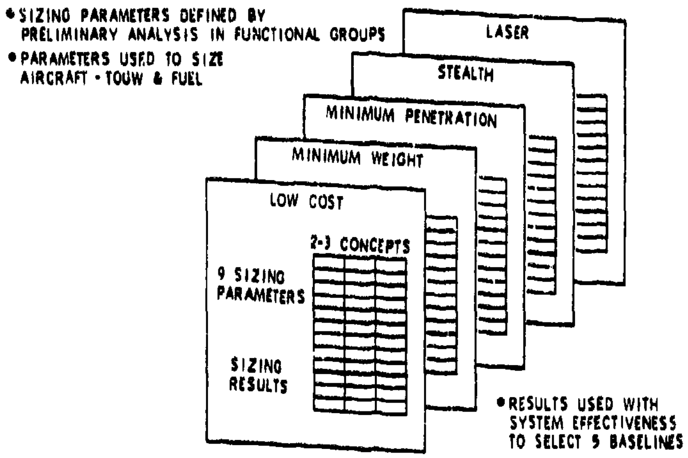
CONCEPTUAL SKETCH ASSESSMENT

(U) These concepts were qualitatively rated to select the best two or three concepts in each category. This was accomplished by having members of the functional groups (Aerodynamics, Propulsion, Weights, Manufacturing, Structures, Stealth, Performance, and Operations Analysis) rate several evaluation parameters for each concept relative to the other concepts in that category (Figure 57). A package was prepared and distributed for each category, consisting of instructions, the concepts in that category, the technologies applied to each concept, and a rating form. The completed forms are available in Appendix B.



(U) Figure 57. Qualitative sketch assessment. (U)

(U) No attempt was made to extract a final numerical total from which the "best" concepts could be mechanically picked. Rather, a committee consisting of the program manager, deputy program manager, and several representatives from functional groups sat down with the raw data representing what the functional groups thought of the concepts, and analyzed the overall merit of each concept. The process followed was a weeding out one in which reasons for not pursuing a specific concept were sought. These reasons included high technical risk, marginal benefits, unacceptable cost impacts, and failure to fit the ISADS Statement of Work. This process was followed until only two to three candidate concepts remained in each category. In some cases, a candidate concept combined features of several conceptual sketches.



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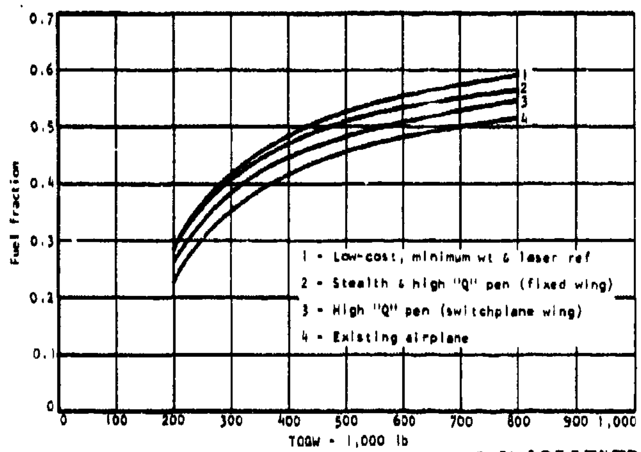
(U) Figure 58. Baseline selection (U)

CANDIDATE CONCEPT ASSESSMENT

(U) These candidate concepts were then subjected to a preliminary sizing exercise to select one baseline per category (Figure 58). For each concept under consideration, the following qualitative assessments were made: (1) expected L/D values were estimated within the Aerodynamics Group for each major mission segment, (2) expected SFC values were estimated within the Propulsion Group, and (3) empty weight fraction and fixed equipment weight required to perform the task were estimated within the Mass Properties Group. A summary of these estimates is presented for each aircraft category in Appendix B. Note that these initial estimates tended to be higher than the final sized weights given late in the text. This is due to the difficulty of allowing for advanced technologies in any statistical analysis. However, the relative weight trends were consistant with later results. The mission of interest is a high-low-low-high strategic mission. A complete description of this mission may be found below under "Performance Requirements," herein.

(U) For each concept, the aerodynamic and propulsion data were used to estimate a fuel fraction required to perform the mission. This was accomplished for each concept, as shown in Appendix B. Here, the left set of columns represents data calculated for a current technology airplane for which a detailed performance and design analysis was previously available. This airplane was flown over the ISADS mission to calculate fuel requirements for each segment. Fuel requirements for the corresponding mission segments for each ISADS concept were ratioed from the known airplane using the cruise efficiency factor $\left\{\frac{ML/D}{SFC}\right\}$. Fuel fraction required was then calculated by summing up fuel used and dividing by an assumed gross weight of 395,000 pounds (for compatability with the known airplane). This required fuel fraction was assumed to remain constant with gross weight. (U)

(U) Fuel fraction available versus gross weight plots was constructed assuming that empty weight fraction and fixed equipment remain constant (Figure 59). Gross weight to perform the mission may now be estimated for each concept by the intersection of fuel fraction required and fuel fraction available curves. These results are recorded at the bottom of the sizing forms in Appendix B. The minimum takeoff gross weight concept was selected as baseline in each category.



(U) Figure 59. Fuel fraction required versus take-off gross weight. (U)

BASELINE SIZING

PERFORMANCE REQUIREMENTS

(U) Performance items calculated for these five baselines consisted of the following:

1. Strategic mission range
2. Theater mission range
3. Standoff mission range
4. Takeoff distance over a 50-foot obstacle

(U) A description of each mission profile is presented in Figures 60 through 62. All mission performance is calculated assuming 1962 U.S. Standard Atmosphere conditions. No fuel flow service tolerance was applied during mission performance calculations (i.e., fuel flows assumed are identical to those shown in the preceding for installed propulsion performance).

(S) Takeoff distance is evaluated for sea level, standard day conditions. All engines are assumed to be operating, and distance calculated is that required to clear a 50-foot obstacle.

Performance items considered as requirements for airplane sizing purposes are:

1. Strategic mission range = 5,250 n mi

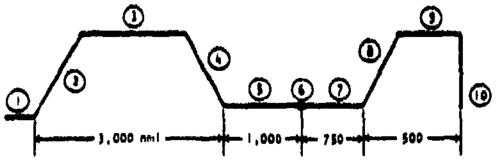
2. Takeoff distance = 6,000 ft

(U) Range on the theater mission and loiter on the standoff mission were considered to result from strategic mission fuel requirements.

VEHICLE SIZING AND PERFORMANCE EVALUATION PROGRAM

(U) All performance and sizing calculations were made using the Rockwell Vehicle Sizing and Performance Evaluation Program (VSPEP). This computer program is a design tool capable of scaling a known basepoint vehicle according to specified values of several different design parameters. These include vehicle gross weight (or fuel weight), thrust-to-weight ratio (or engine size), wing loading (or wing area), and payload or fixed equipment weight and volume. Performance may be determined at specified gross weight or, alternatively, a search routine permits automatic sizing of the vehicle gross weight such that a specified radius or range of the design mission is satisfied. Vehicle performance is calculated internally from a set of sub-routines programmed according to a detailed performance analysis model. The subroutines are general in nature and permit calculation of a wide variety of mission profiles. Several mission profiles may be calculated simultaneously. Takeoff and landing distances and maneuvering capability may also be determined. Figure 63 illustrates the evaluation process.

(U) Typical mission legs which may be calculated include warmup, taxi, takeoff, climb, descent, cruise, and loiter operations. Climb and descent performance are determined by numerical integration of the equations of motion along a specified flight schedule. Internally generated schedules are also available, including minimum time and minimum fuel flight paths as defined by the energy method. Constraints on the allowable flight regime are included. Cruises and loiters may be determined at fixed or optimum speeds and altitudes. Numerical searches are used to determine optimum speeds and altitudes at the beginning and end of each of these legs.



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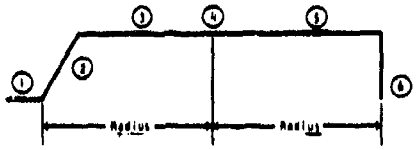
1. Warmup and takeoff - 5 minutes at maximum dry power.
2. Climb to altitude and mach number for best cruise.
3. Proceed at altitude and mach number for best cruise for 3,000 n mi prepenetration range.
4. Descend to 200-foot altitude.
5. Dash 1,000 n mi at 200-foot altitude and mach 0.72 (mach 1.2 for high "Q" penetrator)
6. Extend 50,000 lb payload on target.
7. Withdraw 750 n mi at 200-foot altitude and mach number for best range.
8. Climb to altitude and mach number for best cruise.
9. Cruise at altitude and mach number for best range for a distance of 500 n mi.
10. Land with 30-minute fuel reserve at maximum endurance speed at sea level, plus 5% initial fuel load.

(U) Figure 60. Mission I (strategic). (U)



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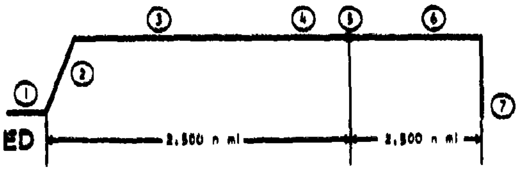
1. Warmup and takeoff - 5 minutes at maximum dry power.
2. Climb to altitude and mach number for best cruise.
3. Proceed at altitude and mach number for best cruise.
4. Deliver payload on target (50,000 lb).
5. Return to base at mach number and altitude for best cruise.
6. Land with 30-minute fuel reserve at maximum endurance speed at sea level, plus 5% initial fuel load.

(U) Figure 61. Mission II (theater with alternate payloads). (U)



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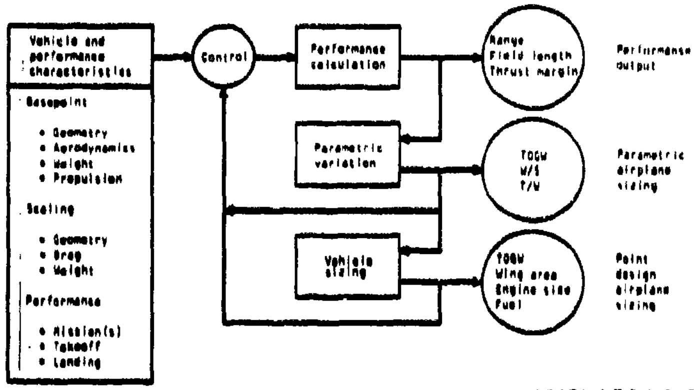
1. Warm-up and takeoff - 5 minutes at maximum dry power.
2. Climb to best cruise speed and altitude.
3. Cruise at best speed and altitude for maximum range to patrol a perimeter of 2,500 n mi distance from base.
4. Patrol at best speed and altitude for maximum endurance.
5. Launch 50,000 lb payload.
6. Return to base at best speed and altitude.
7. Land with 30-minute fuel reserve at maximum endurance speed at sea level, plus 5% initial fuel load.

(U) Figure 62. Mission III (standoff). (U)



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(U) Figure 63. Vehicle sizing and performance evaluation program. (U)

Data input to the VSPEP for each ISADS basepoint vehicle include:

1. Weights broken down by major component, along with scaling information on the wing, tails, fuselage, and engines

2. Drags broken down by major component and type (e.g., friction drag, wave drag, drag-due-to-lift, base drag)

3. Installed propulsion data, including thrust and fuel flow as functions of speed, altitude, and power setting

4. Dimensional data such as lengths, areas, and volumes for major components and total vehicle

Derivation of these inputs is described in the following paragraphs. (U)

AERODYNAMIC CHARACTERISTICS

(U) Presented herein are aerodynamic lift and drag data used in sizing the five ISADS concepts. Presented are lift and drag data consisting of skin friction, drag-due-to-lift, compressible drag rise, and drag increments due to boundary layer diverter (BLD) and base. Also presented are landing gear drag and flaps-down lift and drag data. These data are based on the following initial trapezoidal wing geometries:

ISADS Concept	$S_{REF.}$ (ft^2)	$\bar{c}$ (in.)	b (in.)	AR	λ	Λ_{LE} (deg)
1 - D645-1 (min cost)	1,800	207.9	1,247.1	6	1.	-22
2 - D645-6 (min weight)	3,333	400.0	1,200.0	3	1.	30
3 - D645-3 (min pen. time)	2,550	262.5	1,484.3	6	.4	8
4 - D645-4 (stealth)	3,960	627.3	1,068.0	2	.16	55
5 - D645-5 (defensive laser)	4,200	435.5	1,555.4	4	.25	35

(U)

(S) In the concept III skewed wing configuration, the following wing sweep schedule was assumed:

Flight Mode	Λ_{LE} (deg)
Cruise at BCM/BCA	25°
Penetration at 1.2M /200 ft	98° (wing folded)
Takeoff and landing	8° (wing fully extended)
Withdrawal at BCM/200 ft	65°

(U) The following wing and control surface design criteria were assumed in estimating the aero data:

Concept	Airfoil	LE	$CL_{DES.}$	LE Device	TE Flap Type	b_f/b_w	c_f/c_w	δF
1	10% SC	-2	0.5	Yes	SSF	0.585	0.2	20°
2	12% SC	30	.3	No	SSF	.86	.1	20°
3	5.5% std	25	.5	Yes	-	-	-	-
3	(body lift)	98	-	-	-	-	-	-
3	6%	8	.1	Yes	DSF	.785	.25	30%
3	2.6%	65	.2	Yes	-	-	-	-

4	14%	55	.3	Yes	SSF	.689	.2	20%
5	14% SC	35	.3	Yes	SSF	.545	.25	10%

NOTE: SC = Supercritical Airfoil

SSF = Single Slotted Flap

DSF = Double Slotted Flap

LE = Leading Edge

TE = Trailing Edge (U)

Skin Friction Drag

(U) Skin friction drag was estimated using the computer program described in Reference 10. The program employs several well-established semiempirical techniques to estimate the viscous drag of an arbitrary aircraft configuration using a component buildup approach. The program evaluates laminar and turbulent flap plate skin friction at incompressible and compressible speeds, and provides specified or flatplate natural transition point calculation options in conjunction with a matching of the momentum thickness to link the two boundary layer states. For the turbulent condition, the increase in drag due to distributed surface roughness is treated using uniformly distributed sand grain results. Component thickness effects are approximated using experimental data correlations for 2-D airfoil sections and bodies of revolution.

(U) Natural transition on all lifting surfaces and bodies was assumed (equivalent sand grain height (ks) of 0.000033 ft), reflecting standard camouflage paint of average application. A standard 10-percent allowance for surface irregularities was not added to the computed skin friction drag, assuming that this increment is offset by a reduction in skin friction drag by application of surface coatings on the baseline vehicles.

(U) The computed skin friction drag values at mach 0.6 and 25,000 feet (K = 0.000033 feet) are tabulated in the following. The friction drag values at other mach numbers and altitudes are computed by the vehicle performance evaluation program using these basepoint data.

Concept	C_{D_p}	S_{REF}	S_{WET}	C_f
1 - Low cost (D645-1)	0.01112	1,800 ft^2	8,790 ft^2	0.00228
2 - Min weight (D645-6)	.00684	3,333	9,347	.00244

3 - Min penetration time (D645-3)	.01009	2,550	12,310	.00209
4 - Stealthy (D645-4)	.00584	3,960	8,926	.00259
5 - Defensive laser (D645-5)	.00690	4,200	11,387	.00255

(U)

Boundary Layer Diverter and Base Drag

(U) Drag increment due to the boundary layer diverter of the D645-3 (minimum penetration time concept) configuration was computed using the experimental data correlation contained in Reference 11 and is presented as Figure C-1. Base drag increment due to the fuselage aft end of the D645-1 (low-cost concept) is also estimated based on available experimental correlation.

Drag Divergence Mach Number, Compressible Drag Rise, and Wave Drag

(U) Drag divergence mach number (M_{DD}) and compressible drag rise (ΔC_{D_M}) due to lifting surface were estimated using available data correlation and are presented in Figures C-2 and C-3. Wing leading edge sweep angle, wing thickness ratio, and airfoil type (standard or supercritical) are the variables in determining the drag divergence mach number. The compressible drag rise presented in Figure C-3 is presented as a function of a ratio of flight mach number to drag divergence mach number (M/M_{DD}). Therefore, to determine drag rise at any flight condition (altitude, Mach number, and lift coefficient), Figure C-3 must be used in conjunction with the drag divergence mach number plots of Figure C-2.

(S) The minimum penetration time concept vehicle (D645-3) has a penetration speed of mach 1.2 at 200 feet with its wing fully skewed. For this flight mode, wave drag was evaluated using LAD's computer-aided digitizing and aerodynamic preliminary analysis system (PAD), described in Reference 12 and shown in Figure C-4. The actual wave drag level used for this vehicle sizing is denoted as "goal." This level is desired through configuration refinement, which requires some further design iteration. The wave drag analysis is based on the far-field theory presented in Reference 13.

Drag-Due-to-Lift

(U) Incompressible drag-due-to-lift (induced drag) was estimated using the aforementioned LAD PAD program (Reference 12 in conjunction with the experimental wing leading edge suction correlation (Figure C-5). Zero- and 100-percent-suction induced drag factors are first evaluated by PAD. For a selected suction (S) curve corresponding to an assumed design lift coefficient ($C_{L_{DES}}$), the drag-due-to-lift factor (C_{D_i}/C_L^2) is computed for a range of lift coefficient, as follows:

$$\frac{C_{D_i}}{C_L^2} = \left(\frac{C_{D_i}}{C_L^2}\right)_{S=0} - s\left[\left(\frac{C_{D_i}}{C_L^2}\right)_{S=0} - \left(\frac{C_{D_i}}{C_L^2}\right)_{S=100}\right]$$

In the preceding equation, the 100-percent-suction induced drag factor $(C_{D_i}/C_L^2)_{S=100}$ will approach $1/\pi AR$ (AR = reference wing aspect ratio) for a wing planform without winglets (or tip-mounted vertical tails). With wing-tip vertical surfaces, $(C_{D_i}/C_L^2)_{S=100}$ comes out lower than the basic wing showing the end plate effect. The 0-percent-suction induced drag factor $(C_{D_i}/C_L^2)_{S=0}$ is nothing more than $C_L \tan \alpha/C$. The following tabulates computed values of the aforementioned factors at mach 0.7.

Concept		C_L	$\left(\frac{C_{D_i}}{C_L^2}\right)_{S=0}$	$\left(\frac{C_{D_i}}{C_L^2}\right)_{S=100}$	AR	$\frac{1}{\pi \cdot AR}$	$C_{L_{DES}}$
1 - D645-1 (low cost)		0.1076	0.1622	0.0527	6	0.0531	0.5
2 - D645-6 (min wt)		.0669	.2609	.0827	3	.1061	.3
3 - D645-3	$\Lambda_{LE} = 65°$	.0477	.3659	.1386	2.38	.1338	.2
(min pen. time)	$\Lambda_{LE} = 25°$	.0927	.1883	.0541	5.81	.0548	.5
	$\Lambda_{LE} = 8°$	.1012	.1725	.0527	6	.0531	.1
4 - D645-4 (stealthy)		.0503	.3470	.1344	2	.1592	.3
5 = D645-5 (defensive laser)		.0836	.2038	.0615	4	.0796	.3(U)

(U) The low-speed flaps-down lift and drag-due-to-lift for takeoff and landing were estimated using empirical methods outlined in References 14 and 15.

(U) The drag-due-to-lift factors are presented in Figures C-6 through C-10 and the low-speed lift data are presented in Figures C-11 through C-15.

Landing Gear Drag

(U) Drag increment due to landing gear is based on an analysis of B-1 data and is presented in Figure C-16 based on total nose and main tire frontal area (not including the frontal area of the strut). To obtain landing gear drag increment for any one of the ISADS concepts, ΔC_{π} of Figure C-16 must be multiplied by the ratio of the total nose and main tire frontal area to the concept reference area. The B-1 employs a pair of dual two-in-tandem main gear arrangement, concepts 1 and 4 (D645-1 and -4) employ a pair of dual three-in-tandem main gear arrangement, and concept 3 (D645-3) employs a pair of dual wheels with very short struts for both the nose and main gears. To account for variation in gear drag for these situations, the frontal area presented in Figure C-16 is adjusted for each unique gear arrangement. (U)

Total Drag

(U) Total drag represents a summation of the various increments using the expression:

$$C_{D_{TOTAL}} = \underbrace{C_{D_p} + \Delta C_{D_{BLD}} + \Delta C_{D_{BASE}} + \Delta C_{D_{M_{C_L\,0}}}}_{\text{Drag at zero lift}}$$

$$+ \underbrace{\left(\frac{C_{D_i}}{C_L^2}\right) C_L^2 + \Delta C_{D_{M_{C_L = X}}}}_{\text{Induced drag}} + \left(\Delta C_{D_{L_G}}\right)$$

WEIGHTS

(U) Air vehicle weights presented herein for the five baseline configurations reflect projected advancements in state-of-the-art (SOA) for the 1995 time period. Advanced technologies applied to the vehicle basic structure include the use of new metal and composite materials, in addition to advanced fabrication/manufacturing techniques. The new materials have increased strength-to-weight ratios and higher design allowables, yielding a weight reduction. Advanced fabrication/manufacturing methods provide capability to form large sections of integral composite structure and large sections of SPF/DB structure, resulting in both a weight and cost savings. The propulsion group has advanced engines with high thrust-to-weight ratios. Projected technology progress for the various vehicle subsystems are included with the system weights.

(U) The approach used to estimate structure weights on the ISADS baseline concepts was the development of equivalent conventional construction aircraft component weights to which were then applied postulated achievable weight-saving increments for advanced material, design, and manufacturing applications.

Statistical methods formulated from a data base of existing hardware were used to estimate the structure weight of components constructed with conventional materials and methods. Adjustments were made to these statistical estimates to account for unique concept-oriented features such as wing-body blending, winglet effects, and span loading arrangements. (U)

(U) TABLE 10. STRUCTURE WEIGHT SAVINGS FOR ADVANCED CONSTRUCTIONS (YEAR 1995) (U)

Component	Minimum cost			Minimum weight		
	Advanced composite		metallic	Advanced composite		metallic
	Comp (%)	Savings (%)	Savings (%)	Comp (%)	Savings (%)	Savings (%)
Wing	80	26.5	-[a]	80	36.5	-
Horizontal tails (canard)	80	26.5	-	80	36.5	-
Vertical tails	80	26.5	-	80	36.5	-
Fuselage	70	16.5	5	70	22.5	12
Landing gears	40	17.5	12	40	27.5	16
Nacelles & engine section	-	-	10	-	-	14.5

[a] Not considered on ISADS concepts.

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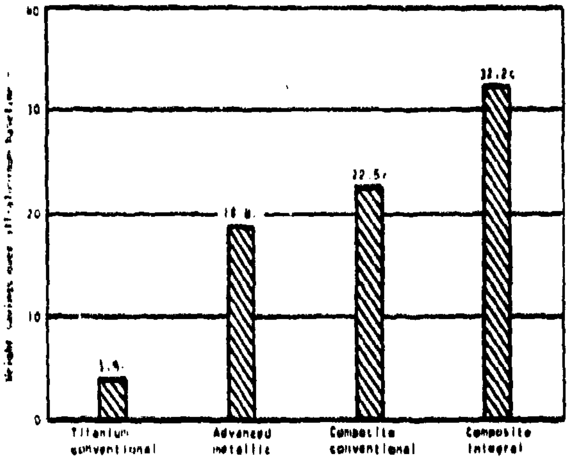
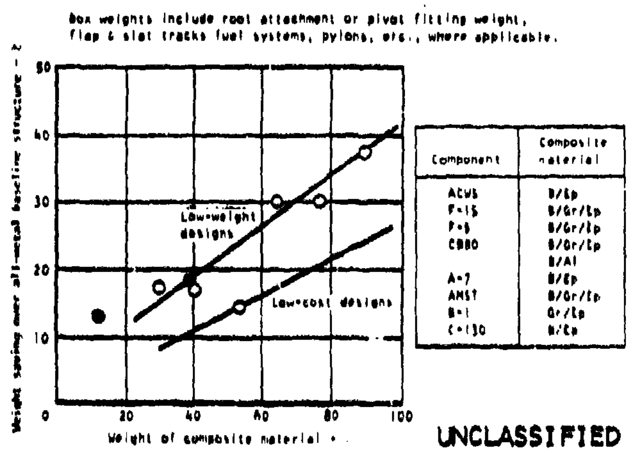
(U) Table 10 presents the weight savings that were assumed for both advanced composite and metallic designs which were applied to the statistically estimated component weights. These weight-saving increments for both design-to-cost and design-to-weiht concepts were derived by reviewing Rockwell design studies and actual fabrication programs on advanced composite and metallic constructions combined with known results attained by other aircraft companies. Figures 64 and 65 show typical wing structure weight-saving data that were used. Projected technology advancements were consolidated with the foregoing weight-saving achievements to arrive at the technology design base for the post-1995 time period.

(U) Similar to vehicle structure, the weights for subsystems were derived by applying predicted weight reductions to statistically determined system weights. These weight savings result from the use of advanced technologies, such as high-pressure hydraulic system, high-voltage electrical system, fiber optics, mini-micro electronics, composite material, etc. The weight reductions assumed for the vehicle subsystems are shown in Table 11.



(U) Figure 64. Advanced construction concepts wing weight savings, critical component development program. (U)



(U) Figure 65. Advanced composite wing box weight savings. (U)

(U) TABLE 11. SYSTEM WEIGHT SAVINGS ASSUMED FOR 1995 SOA TECHNOLOGIES (U)

System	Weight reduction (%)
Accessory gearbox	5
Engine controls	5
Starting system	5
Fuel system	20
Flight controls	10
Instruments	10
Hydraulics	20
Electrical	5
Avionics	20
Armament	10
Furnishings	10
Air conditioning	20

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(U) Appendix D summarizes the weights data for the five baseline configurations, as initially drawn. These data were used as input to the vehicle sizing program, from which final weights were produced. These final weights are given in the text starting on page 209.

PROPULSION

(U) In the absence of engine manufacturers' engine performance computer programs for 1995 engines, the Rockwell propulsion analysis program was used to compute installed propulsion system performance. This program is basically an engine cycle analysis program extended to compute overall propulsion system performance, including inlet and nozzle effects. Real thermodynamic properties are included in curve fit form. All component characteristics, including inlet and nozzle, are input in map form. The program is written in FORTRAN and is based on the program developed under NASA Ames Contract NAS2-2985, "Study of Performance and Weight Analysis of Air Breathing Propulsion Systems for Hypersonic Aircraft." This computer program is capable of computing performance and estimated engine weight, length, diameter, and exhaust jet noise for several turbocycle engine configurations, including turbojet, turbofan, and turbo-derivative propulsion systems. The program has been used extensively to generate propulsion data for advanced study aircraft and to optimize propulsion system performance.

(U) Inlet and nozzle/afterbody performance characteristics were estimated using theoretical analyses and existing data from tests of similar configurations.

Low-Cost Concept Propulsion

(U) A propulsion system was selected and installed performance was computed for use in the low-cost baseline aircraft. The following paragraphs describe the procedure for selecting the propulsion system and the selected propulsion system.

(C) Because this aircraft has no supersonic operational requirement, a pitot-type inlet was selected. Inlets with ramps, cones, and/or variable geometry offer no performance advantage in subsonic flight, and they are more complex and heavier than pitot inlets.

(C) To select an engine cycle, weight and performance data at selected conditions were computed for a range of mixed-flow engines, including moderate-bypass-ratio augmented engines and high-bypass-ratio dry engines. The Rockwell propulsion analysis computer program was used for these engines. In addition, advanced versions of existing engines were postulated. However, no existing engines have the thrust characteristics required for these vehicles. Preliminary estimates of thrust requirements indicated that for penetration at mach 0.7, sea level, the thrust required would be approximately 40 percent of the thrust at sea level, static, takeoff. Ideally, this thrust match can be achieved with a high-bypass-ratio (approximately 7) engine. The high bypass ratio provides good SFC at cruise and penetration and low exhaust gas temperatures for low infrared (IR) signature. However, the diameter of this engine is then about 8 feet, approximately the diameter of the fuselage. The large engine face diameter causes a severe radar cross-section (RCS) problem. Thus, in order to reduce the RCS problem, moderate bypass ratio engines with augmentation were examined. (C)

(U) From engine design and maintenance viewpoints, it is desirable to have turbines which require no cooling flow. Garrett AiResearch indicated that the maximum turbine inlet temperature that could be used with no turbine cooling flow would be 2,400° F for IOC in the year 2000. A higher temperature is desired to minimize engine size. Therefore, the temperature was increased (and high-pressure turbine cooling flow was added) to a point where the low-pressure turbine inlet temperature was near 2,400° F; therefore, the low-pressure turbine would not require cooling flow. Thus, the selected cycle has a fan pressure ratio of 3.7, a bypass ratio of 1.7, an overall pressure ratio of 35, and a combustor exit temperature of 3,000° F. This cycle provides a good vehicle thrust requirement match and has no low-pressure turbine cooling flow. The selected propulsion system has been designated MF78-01. The engine characteristics and weight and dimensional data are presented in Table 12. Component performance levels used are presented in Table E-1. Installation effects are summarized in Table E-2. The engine uses a variable convergent-divergent axisymmetric nozzle.

(U) TABLE 12. MF78-01 ENGINE CHARACTERISTICS (U)

Sea-level static, maximum power thrust, lb	
Uninstalled	65,000
Installed	60,000
Design air flow, lb/sec	550
Bypass ratio	1.7
Combustor discharge temperature, °F	3,000
Overall pressure ratio	35
Fan front face diameter, in.	55
Maximum diameter (at nozzle), in.	55
Overall length, in.	192
Center of gravity, in. from fan front face	74
Dry weight, lb	5,400

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Minimum-Weight Concept Propulsion

(U) From a propulsion viewpoint, the minimum-weight concept propulsion system installation and thrust requirements are basically identical to those of the low-cost concept. Therefore, the low-cost propulsion system and its performance were used for the minimum-weight aircraft.

Minimum Penetration Time Concept Propulsion

(U) A propulsion system was selected and installed performance was computed for use in the baseline minimum penetration time aircraft. The following paragraphs describe the procedure for selecting the propulsion system and the selected propulsion system.

(S) Because the maximum mach number is only 1.2, a pitot-type inlet was selected. Inlets with ramps, cones, and/or variable geometry offer no performance advantage for this airplane, and they are more complex and heavier than pitot inlets. A 2-D plug nozzle with vectoring for pitch control was selected.

(S) To select an engine cycle, weight and performance data at selected conditions were computed for a range of cycle parameters for (1) multimode integrated propulsion systems (MMIPS), and (2) mixed-flow engines with variable geometry, low-pressure turbines and variable geometry mixers (similar to the General Electric variable area bypass injector (VABI) concept). While MMIPS cycles were found to provide slightly better installed performance, MMIPS cycle was not selected because of the complexity of the installation. The Rockwell propulsion analysis computer program was used for these engines. Preliminary estimates of thrust requirements indicated that for penetration at mach 1.2, sea level, the thrust required would be approximately 45 percent of the thrust at sea level, static, takeoff. From engine design and maintenance viewpoints, it is desirable to have turbines which require no cooling flow (maximum turbine inlet temperature of 2,400° F for IOC in the year 2000). A higher temperature is desired to minimize engine size. Therefore, the temperature was increased (and high-pressure turbine cooling flow was added) to a point where the low-pressure turbine inlet temperature was near 2,400° F; therefore, the low-pressure turbine would not require cooling flow. Thus, the selected cycle has a fan pressure ratio of 3.4, a bypass ratio of 2.0, an overall pressure ratio of 35, and a combustor exit temperature of 3,000° F. Combustor exit temperature is allowed to increase to 3,100° F at mach 1.2, sea level, maximum power. This cycle provides a good vehicle thrust-requirement match and has no low-pressure turbine cooling flow. While some optimizing of variable low-pressure turbine and mixer areas was done, the propulsion performance is not to be considered optimum. Some performance gains should be realized by varying cycle, turbine, and mixer. The selected propulsion system was designated MF78-02. The engine characteristics and weight and dimensional data are presented in Table 13. Component performance levels used are presented in Table E-3. Installation effects are summarized in Table 4. The engine uses a variable flap, expandable 2-D plug nozzle.

(U) TABLE 13. MF78-02 ENGINE CHARACTERISTICS (U)

Sea-level static, maximum power thrust, lb	
Uninstalled	62,250
Installed	50,400
Design airflow, lb/sec	550
Bypass ratio	2.0
Combustor discharge temperature, °F	3,000
Overall pressure ratio	35
Fan front face diameter, in.	55
Maximum diameter (at nozzle), in.	55
Overall length, in.	192
Center of gravity, in. from fan front face	75
Dry weight, lb (includes axisymmetric nozzle and 5% allowance for variable-geometry turbine and mixer)	5,450
Axsymmetric nozzle weight, lb	640
2-D nozzle weight, lb	1,800

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Stealthy Concept Propulsion

(U) Initially, it was desired to keep the engine diameter and inlet size small for the stealth concept so as to minimize RCS. Therefore, the propulsion system performance data used on the low-cost aircraft were also used on the stealthy aircraft. Nozzle weight was adjusted because the stealth aircraft uses 2-D nozzles.

(U) After the aircraft was sized, it was determined that the aircraft could accommodate large-diameter engines and larger inlets. Thus, it is recommended that additional studies be made incorporating high-bypass-ratio unaugmented engines. These engines would reduce fuel consumption and significantly lower IR signature (because of much lower exhaust gas temperature).

Laser Defense Concept

(U) The laser defense aircraft has thrust requirements similar to those of the low-cost aircraft. Therefore, the propulsion system performance data used on the low-cost aircraft were also used on the laser aircraft. Nozzle weight was adjusted because the laser aircraft uses 2-D nozzles.

AIRPLANE SIZING AND SENSITIVITIES

(S) The "as-drawn" basepoint airplane for each of the five airplane concepts was analytically resized toward the objective of obtaining the minimum gross weight (or minimum cost) baseline airplane meeting the performance requirements of 5,250 nautical miles on the strategic mission and a takeoff distance no greater than 6,000 feet. The baseline drawing do not reflect the results of this resizing.

(S) Resizing was accomplished on each concept by exercising the Vehicle Sizing and Performance Evaluation Program (VSPEP) for a matrix of thrust-to-weight and wing loading values, and allowing the program to search for the gross weight in each case that satisfies the design mission range requirement. Takeoff distance is also calculated for each point of the matrix. Both gross weight and takeoff distance plots versus thrust-to-weight (T/W) and wing loading (W/S) were prepared and are presented in the following paragraphs. Several takeoff distance requirement lines are cross plotted onto the gross weight versus T/W and W/S curves. Since takeoff distance is the only performance requirement other than design mission range, the thrust-to-weight, wing loading, and gross weight may now be selected from this design chart for the minimum gross weight airplane to satisfy each of several takeoff distance requirements. The optimized baseline airplanes were selected for each concept for a takeoff distance requirement of 6,000 feet.

(U) Several design and mission sensitivity trades were performed about the selected baselines for each of the five ISADS concepts. Parameters varied consist of the following:

1. Takeoff distance requirement
2. Wing aspect ratio
3. Parasite drag
4. Drag-due-to-lift
5. Engine specific fuel consumption
6. Fixed equipment weight
7. Penetration mach number

(U) In addition to the preceding items, the following parameters were also varied for the low-cost and minimum penetration time (high "Q") baselines:

1. Payload weight

2. Total low-altitude distance (maintaining total range constant at 5,250 and recovery distance constant at 500 nautical miles, respectively) (U)

(U) All of the preceding trades except the takeoff distance requirement trade were performed by independently varying the specified parameter and exercising the VSPEP to resize the airplane to that gross weight required to meet the 5,250-nautical-mile design mission range. Thrust-to-weight and wing loading are held constant at those values selected for the baseline. The takeoff distance requirement trade is plotted directly from the design chart developed earlier. In this case, T/W and W/S are both variable and are equal to those values yielding the minimum gross weight vehicle to meet the requirement.

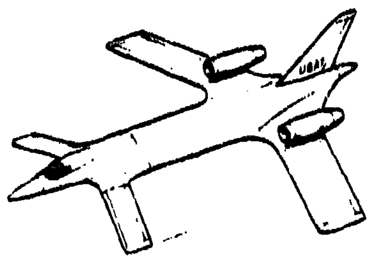
(U) The results of these sensitivity trades are presented in the following paragraphs.

INTEGRATION AND TRADE STUDY RESULTS

(U) Herein, the final, sized baselines and their trade studies are presented. The material is organized such that all data on one concept are presented together.

LOW- COST SIMPLISTIC BASELINE

(U) Figure 66 summarizes the low-cost simplistic baseline. The major feature of note is the high degree to which constant cross sections and flat-wrapped skins are employed. The fuselage is constant in section for two-thirds of its structural length. The wing has a unit taper ratio which can be employed by using the forward-sweep composites technology. This gives a drag-reducing elliptical lift distribution and allows identical ribs from root to tip.



(S) Figure 66. Low cost simplistic baseline. (U)

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(U) Figure 67. Low-cost simplistic. (U)

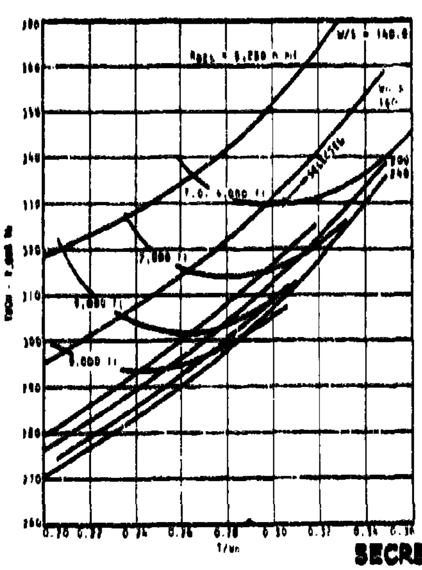
(U) Upper surface podded engines are used because (1) they allow reduced landing gear height without fear of foreign object ingestion, and (2) this allows use of a drag-reducing, favorable pressure interference between the wing and nacelle. Only two engines are used to reduce production and maintenance costs.

(U) The landing gear has several cost-reducing features. The main gears are identically left/right common. Also, the nose gear wheels, tires, and brakes are common with the main gear. In addition, all gears retract directly with simple pivot mechanisms.

The following advanced technologies are employed:

1. Supercritical airfoil
2. Aerodynamic surface coatings
3. Curved composite wing box
4. SPF/DB titanium nacelles
5. Relaxed static stability and fly-by-wire

(U) Performance and sizing charts for the low-cost concept are presented in Figures 69 and 70. The selected baseline airplane was chosen as having T/Wo = 0.306, Wo/S = 165 psf, and Wo = 330,400 lb. This selection was revised, however, as a result of the wing aspect ratio trade, the results of which follow. The final selected baseline is for AR = 8.0 and has T/Wo = 0.302 Wo/S = 170 psf, and Wo = 312,663 lb.



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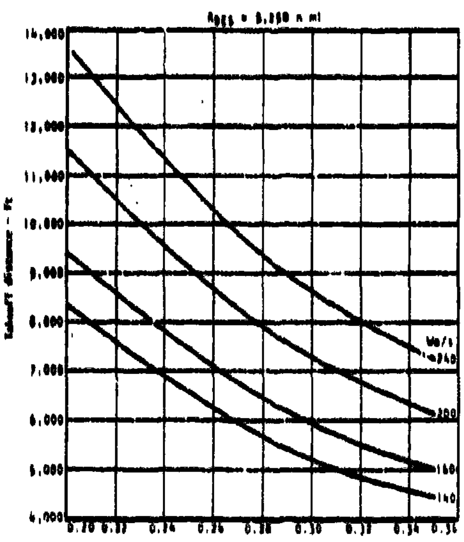
(S) Figure 69. Low-cost design chart (U)



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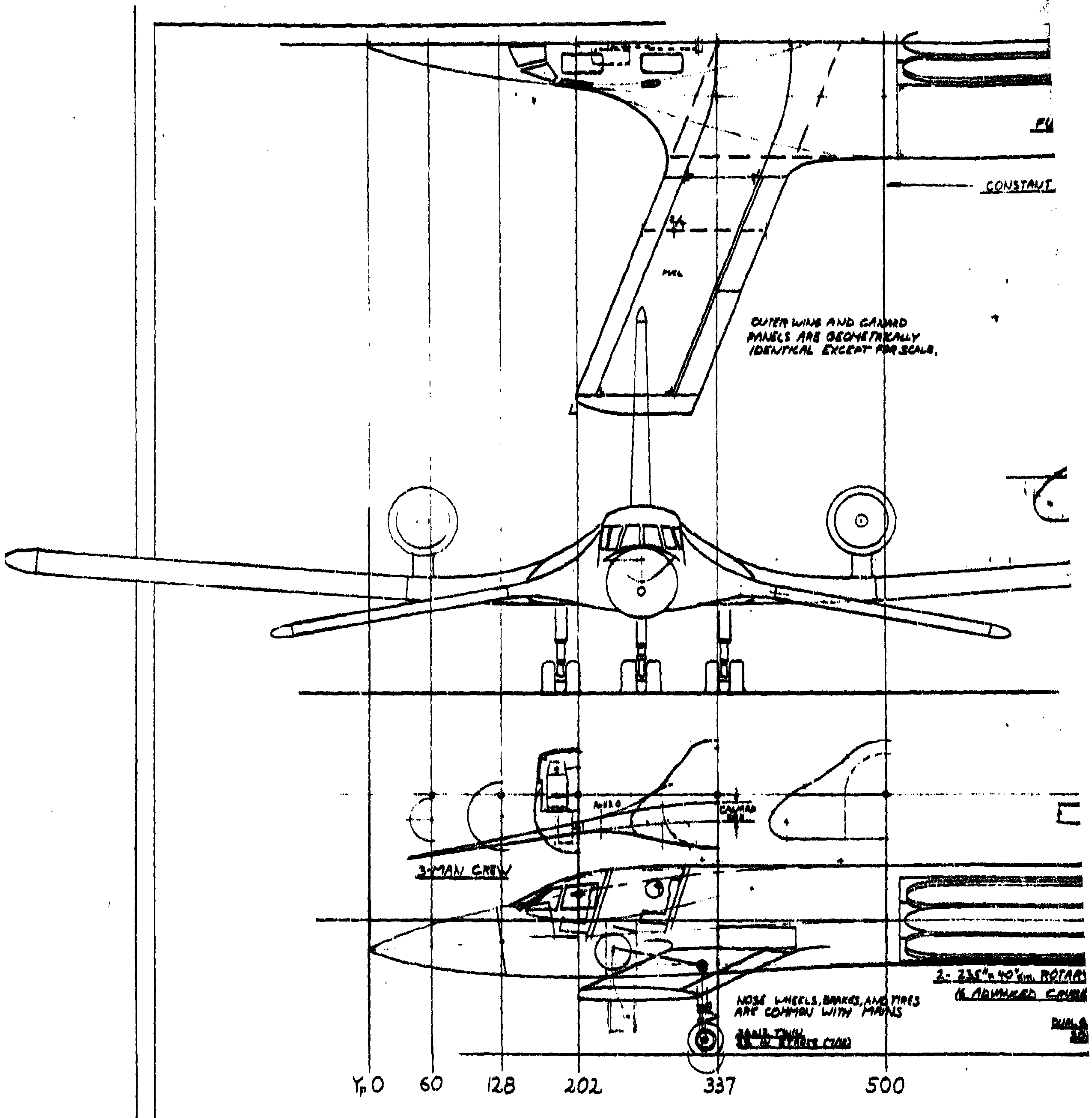
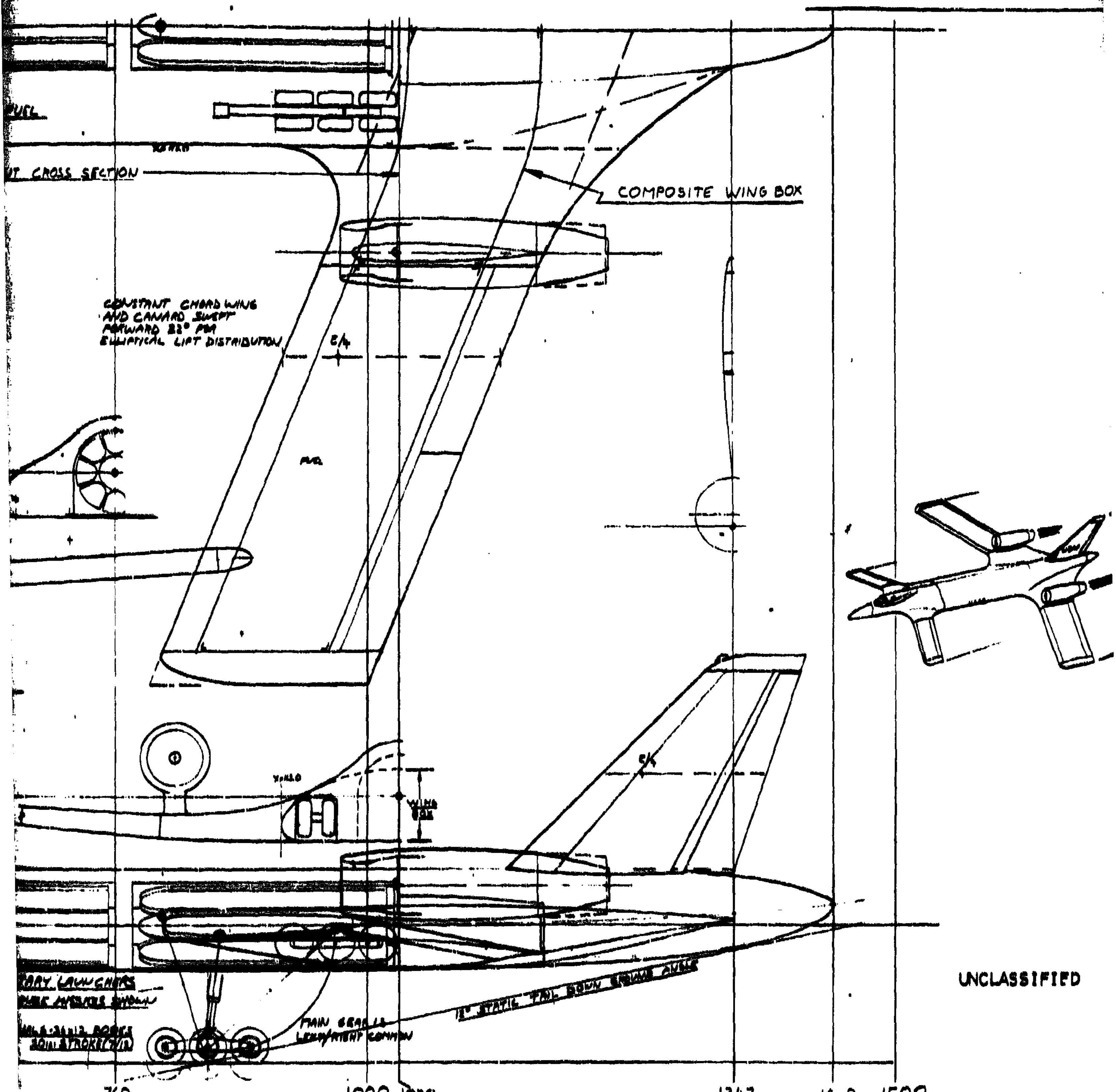
(S) Figure 70. Low-cost takeoff distance (U)


CONSTANT
OUTER WING AND CANARD PANELS ARE GEOMETRICALLY IDENTICAL EXCEPT FOR SCALE.
3-MAN CREW
CANARD
NOSE WHEELS, BRAKES, AND TIRES ARE COMMON WITH MAINS
Yp 0
60
128
202
337
500



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(U) Figure 68.

GEOMETRIC DATA

ITEM	WING (TRAP)	CANARD (TRAP)	VERT. TAIL (TRUE)
S	1800 FT²	600 FT²	200 FT²
AR	6	6	1.5
λ	1.0	1.0	0.3
Λ	−22°	−22°	45°
b	1247.1 IN	720 IN	207.9 IN
C_R	207.9	120 IN	213.2
C_T	207.9	120 IN	64.0
$\bar{c}$	207.9	120 IN	152.0
$\bar{x}/\bar{c}$	311.2	182.3	85.3
Γ	4°	−10°	—
AIRFOIL	10% SUPERCRITICAL	10% SUPERCRITICAL	65A008

PROPULSION

- TWO ADVANCED AUGMENTED TURBOFANS
  THRUST = 55000 EA
  A_c = 1800 IN²

WEIGHTS (EST.)

TOGW = 400,000 LB
W_{WE} = 207,000 LB (CA NZ 45)
W_{PL} = 59,000 LB
$W_{AVIONICS}$ = 4800 LB

NOTES

LOW COST TECHNOLOGIES:

- SIMPLE INTERCHANGEABLE MAIN GEAR, NOSE WHEELS, TIRES AND BRAKES ARE COMMON WITH MAINS.
- CONSTANT CHORD WING AND CANARDS ALLOW CONSTANT RIBS, ETC., WITH INCREASED ROOT BENDING CARRIED BY THICKER COMPOSITE SKIN
- CIRCULAR ARC SEGMENT CONSTANT CROSS SECTION OVER HALF THE FUSELAGE - CONSTANT FRAMES, FLATWRAP SKIN
- MOST COMPOUND CURVES ARE NON-STRUCTURAL - TIPS, FAIRINGS, ETC.
- PYLON MOUNTED ENGINE, ABOVE THE WING FOR FAVORABLE PRESSURE INTERFERENCE
- B1 AVIONICS PACKAGE

ADDITIONAL TECHNOLOGIES

- CURVED COMPOSITE WING BOX REDUCES WEIGHT
- TANDEM WING EFFECT REDUCES FUSELAGE BENDING LOADS
- ACTIVE CONTROLS - FBW, RSS, FLUTTER SUPPRESSION
- RAM AND FILL IN LIGHTS FOR STEALTH

1/50	RAYMER, DATE 18 AUG 77	Rockwell International Corporation	ADVANCED DESIGN
ISADS - MINIMUM COST BASELINE			D 645-1

ISADS - Minimum cost baseline. (U)

(U) A summary of airplane characteristics and performance for the selected low-cost concept is presented in Table 14. Mission summaries for the strategic (design) mission as well as theater and standoff missions are presented in Tables 15 through 17.

(U) Results of sensitivity trades for the low-cost concept are presented in Figures 71 through 74. These trades were performed about the baseline airplane, as selected in the preceding.

(S) TABLE 14. SELECTED LOW-COST CONCEPT CHARACTERISTICS (U)

Takeoff gross weight, lb	312,663
Fuel weight, lb	156,214
Wing loading, psf	170
Thrust-to-weight	.302
Wing area, sq ft	1,839
Wing aspect ratio	8.0
Engine size	.786
Strategic mission range, n mi	5,250
Theater mission radius, n mi	3,943
Standoff mission patrol time, min	339
Takeoff distance, ft	6,012

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(S) TABLE 15. STRATEGIC MISSION SUMMARY FOR SELECTED LOW-COST CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	312,663						
Warmup & T.O.	309,823	0	0.667	2,840	5.00	0	0
Climb	303,763	25,967	.844	6,059	13.62	108.6	108.6
Cruise	236,904	34,393	.844	66,860	381.49	2,891.4	3,000.0
Penetrate	197,957	200	.740	38,947	120.12	1,000.4	4,000.4
Drop	146,986	200	.720	0	0	0	4,000.4
Withdraw	125,083	200	.600	21,903	136.21	750.3	4,750.7
Climb	121,171	30,366	.850	3,912	15.28	120.4	4,871.1
Cruise	116,939	31,118	.850	4,232	46.72	379.6	5,250.7
Loiter	114,254	0	.266	2,685	30.00	0	5,250.7
Reserve	106,449	0	0	7,805	0	0	5,250.7
Total fuel = 156,214 lb							

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(S) TABLE 16. THEATER MISSION SUMMARY FOR SELECTED LOW-COST CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	312,665						
Warmup & T.O.	309,825	0	0.667	2,840	5.00	0	0
Climb	303,754	29,000	.844	6,069	13.65	108.8	108.8
Cruise	218,249	36,147	.844	85,505	467.73	3,834.6	3,943.4
Drop	168,249	36,147	.844	0	0	0	3,943.4
Cruise	116,938	51,176	.850	51,311	486.99	3,943.4	7,886.8
Loiter	114,253	0	.266	2,685	30.00	0	7,886.8
Reserve	106,449	0	0	7,804	0	0	7,886.8
Total fuel = 156,214 lb							

SECRET

(S) TABLE 17. STANDOFF MISSION SUMMARY FOR SELECTED LOW-COST CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	312,665						
Warmup & T.O.	309,825	0	0.667	2,840	5.00	0	0
Climb	303,756	29,000	.844	6,069	13.65	108.8	108.8
Cruise	247,38,	33,675	.844	56,373	290.07	2,391.2	2,500.0
Patrol	199,125	20,005	.824	48,259	339.08	0	2,500.0
Drop	149,125	20,005	.824	0	0	0	2,500.0
Climb	146,598	43,780	.844	2,528	9.65	76.3	2,576.3
Cruise	116,946	51,135	.850	30,652	299.33	3,423.7	6,000.0
Loiter	114,261	0	.266	2,685	30.00	0	6,000.0
Reserve	106,449	0	0	7,812	0	0	6,000.0
Total fuel = 156,214 lb							

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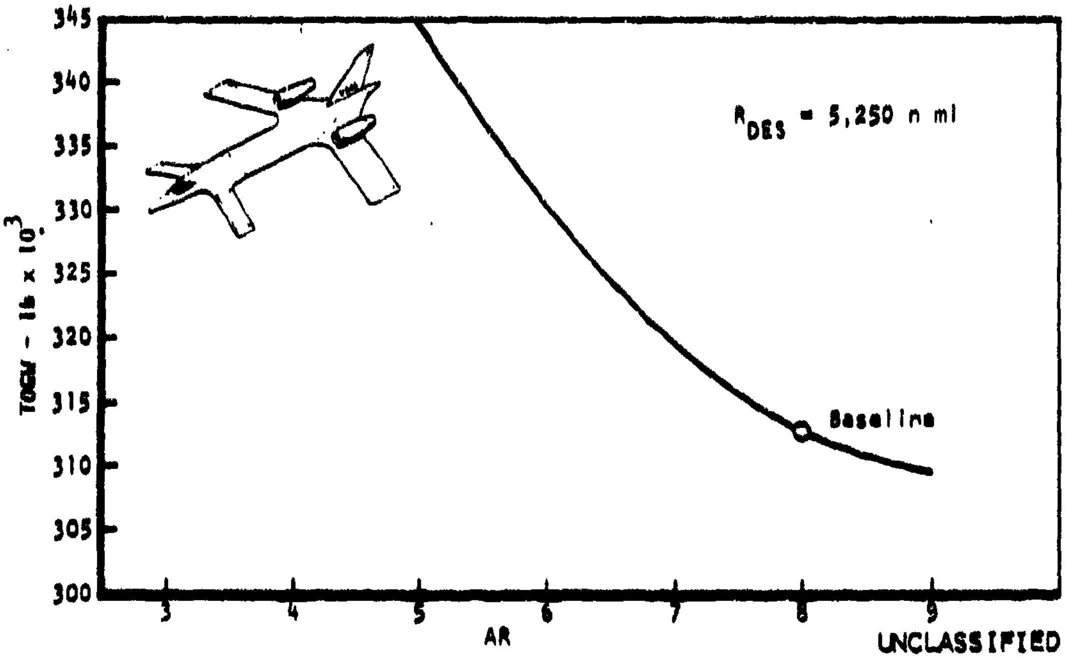
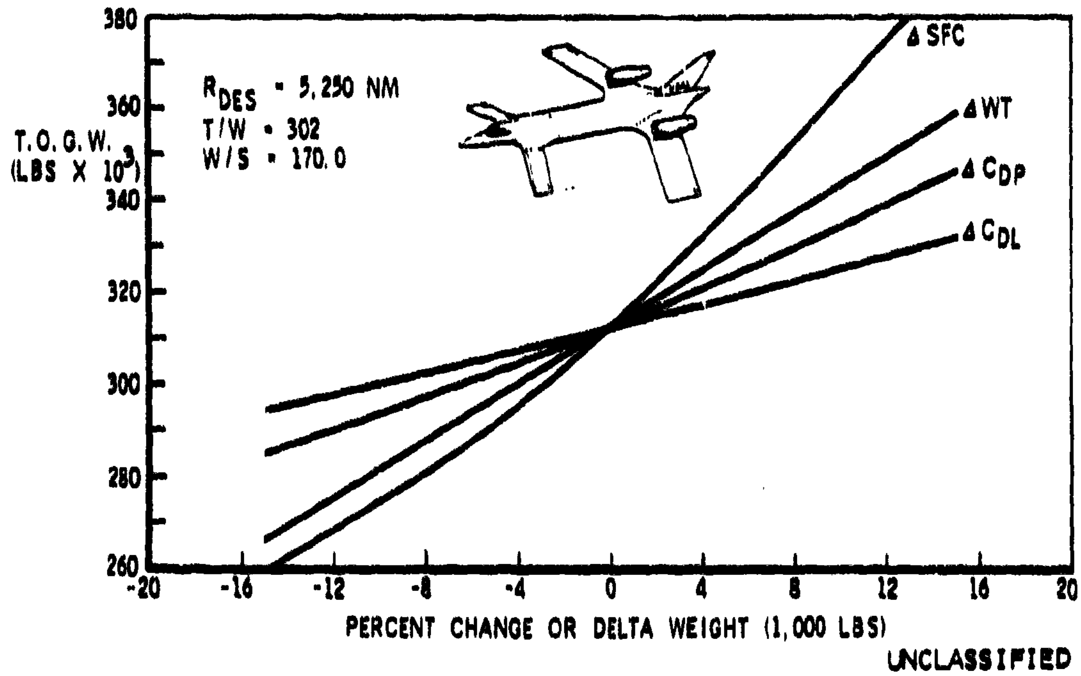
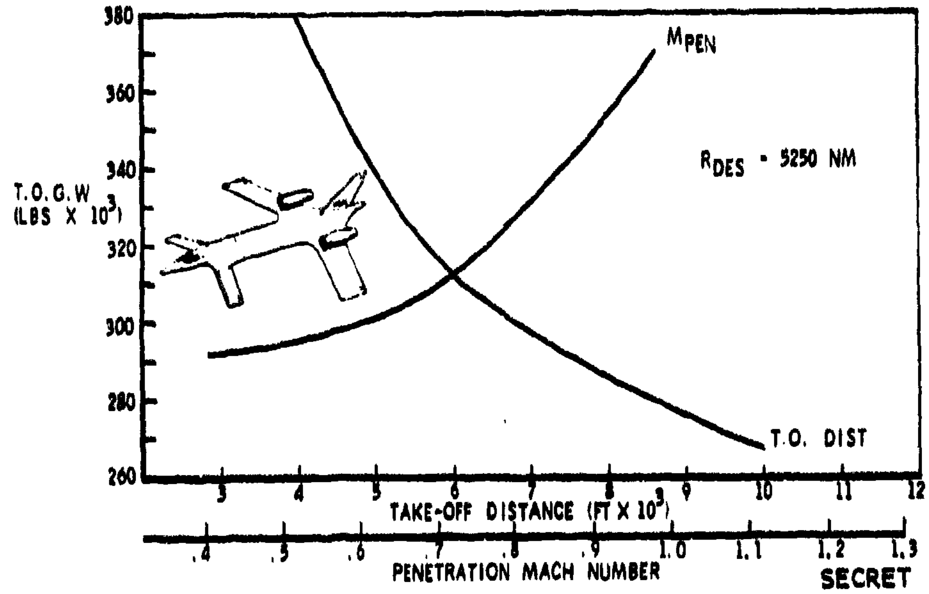


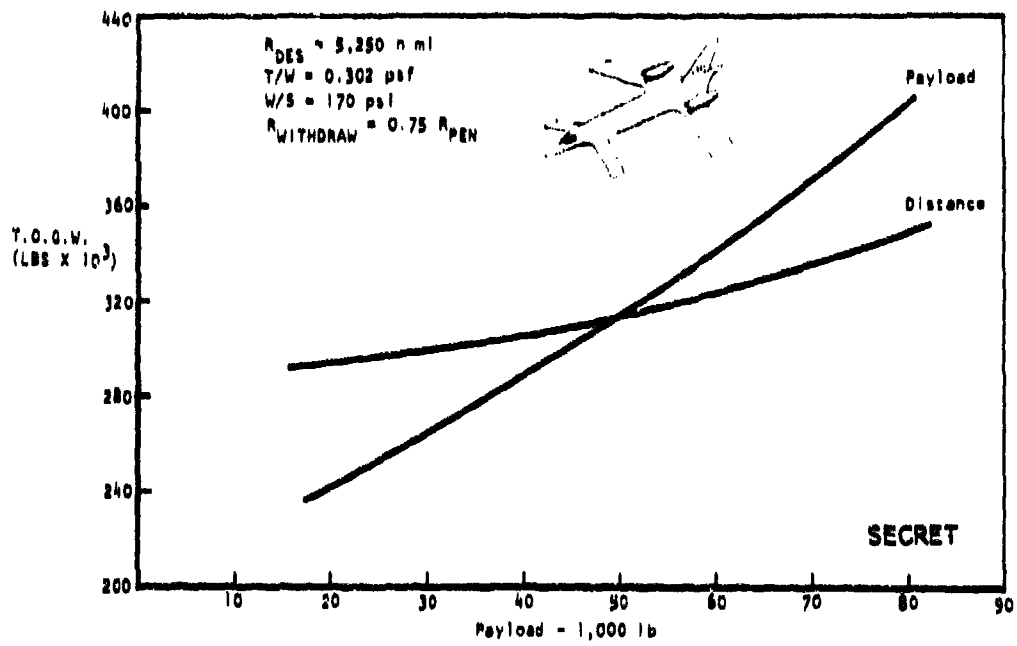
(U) Figure 71. Low-cost aspect ratio trade. (U)



(U) Figure 72. Low-cost concept design sensitivities. (U)

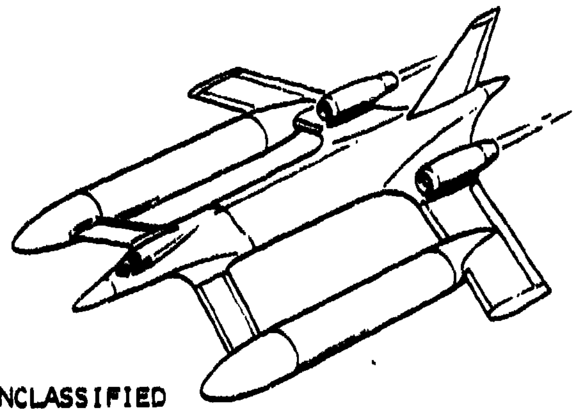


(S) Figure 73. Low-cost concept mission sensitivities. (U)



(S) Figure 74. Low-cost concept payload and low-altitude distance trades. (U)

Low-Cost Simplistic Concept Design Trades



(U) Figure 75. Design trade - liquid hydrogen. (U)

(U) The most interesting design trade performed on the low-cost simplistic concept was the application of liquid hydrogen (Figure 75). The following values were used to obtain the required tank size:

LH_2 = 0.0854 JP

Heat value LH_2 = 2.78 HV_{JP}

2% additional HV required for LH_2

Vol LH_2 = 4.29 vol_{JP}

Wt_{LH_2} = 0.367 $W_{T_{JP}}$

SFC_{LH_2} = 0.0367 SFC_{JP}

Therefore require

W_{LH_2} = 57,330 lb

Vol_{LH_2} = 14,937 ft^3

(U) This requires two Dewar flask tanks, each 40 feet long and 15 feet in diameter. In spite of the greatly reduced fuel weight, the increased drag and structural deadweight resulted in a 23-percent increase in takeoff gross weight. This is primarily due to the denseness of the aircraft. The baseline wetted area is very low relative to the gross weight, when compared to a transport-type aircraft. For this reason, an increase in wetted area has a much larger impact than in other aircraft which have shown to benefit from the use of liquid hydrogen.

	BASELINE	REMOVE SURFACE COATINGS	VARIABLE CAMBER	MANEUVER LOAD CONTROL	VCE
TOGW/LBS	317,663	332,140	309,230	298,300	304,000
WFUEL/LBS	156,214	171,050	152,760	149,040	152,000
WPAYLOAD	50,000	50,000	50,000	50,000	50,000
THRUST	2 X 47,212	2 X 50,153	2 X 46,694	2 X 45,043	2 X 46,000

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(U) Figure 76. Other design trade-Low-Cost-Simplistic. (U)

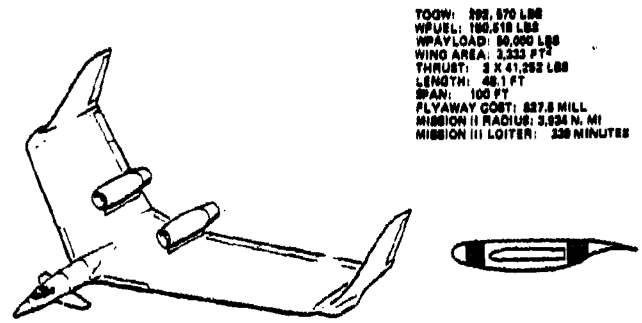
(U) Figure 76 summarizes the other design trades applied to the low-cost simplistic concept. The aerodynamic surface coatings, basically a plastic covering, were shown to have saved 20,000 pounds by their use on the baseline.

(U) Variable camber devices showed a marginal payoff of 3,000 pounds. This would probably not justify their complexity.

(U) Maneuver load control was able to save 15,000 pounds. This is fairly substantial, especially since this technology is close at hand. The trade study was run by recalculating structural weight with the load factor reduced from 3 to 2 and then adding avionics weight. Further pursuit of this is recommended.

(U) A variable-cycle fan engine (VCE) concept with a variable low-pressure turbine and variable-area mixer was examined for use in the minimum-cost simplistic baseline. The variable-geometry features of this concept were estimated to increase engine weight by 5 percent relative to a fixed-geometry engine. It was found that takeoff thrust could be increased approximately 5 percent by varying the geometry to reduce bypass ratio. Thus, no significant improvement in engine thrust-to-weight ratio is expected.

(U) Because the baseline engine for the all-subsonic aircraft has a moderately high bypass ratio of 1.7, variable geometry does not significantly improve subsonic cruise and penetration specific fuel consumption (SFC). It was found that the VCE provided SFC reductions of 1 to 2 percent relative to the fixed-cycle engine. This produced a weight savings of only 6,000 pounds which is probably not worth the complication of a variable-cycle engine.



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- NO ROTARY LAUNCHER REQUIREMENT
- FUEL & PAYLOAD DISTRIBUTED ALONG WING
- TWIN COMPOSITE WING BOXES OPTIMIZED FOR TORSIONAL RIGIDITY

(S) Figure 77. Minimum-weight baseline. (U)

MINIMUM-WEIGHT BASELINE

(U) Figure 77 summarizes the minimum-weight baseline. This is a span-loaded flying wing in which fuel and payload are evenly distributed along the wing for greatly reduced bending loads. Each air-launched cruise missile is carried in a separate bomb bay. This breaks the natural wing torque box, requiring small wing boxes fore and aft of the bomb bays which are optimized for torsional rigidity.

(U) The upper surface nacelles are again used for reduced landing gear height and to obtain a favorable engine/wing pressure interference.

(U) Unlike most spanloader concepts, this one features a canard trimmer to reduce the trim drag frequently associated with tailless aircraft. These surfaces are canted downward sufficiently to allow them to be used as direct side force controls, alleviating the landing approach path control problem typical of flying wings.

(U) Winglets are used to reduce the high induced drag associated with a low-aspect-ratio-constant-chord design, which was necessary to provide sufficient chord length to accommodate the payload. This drag reduction is by comparison to the same wing without winglets.

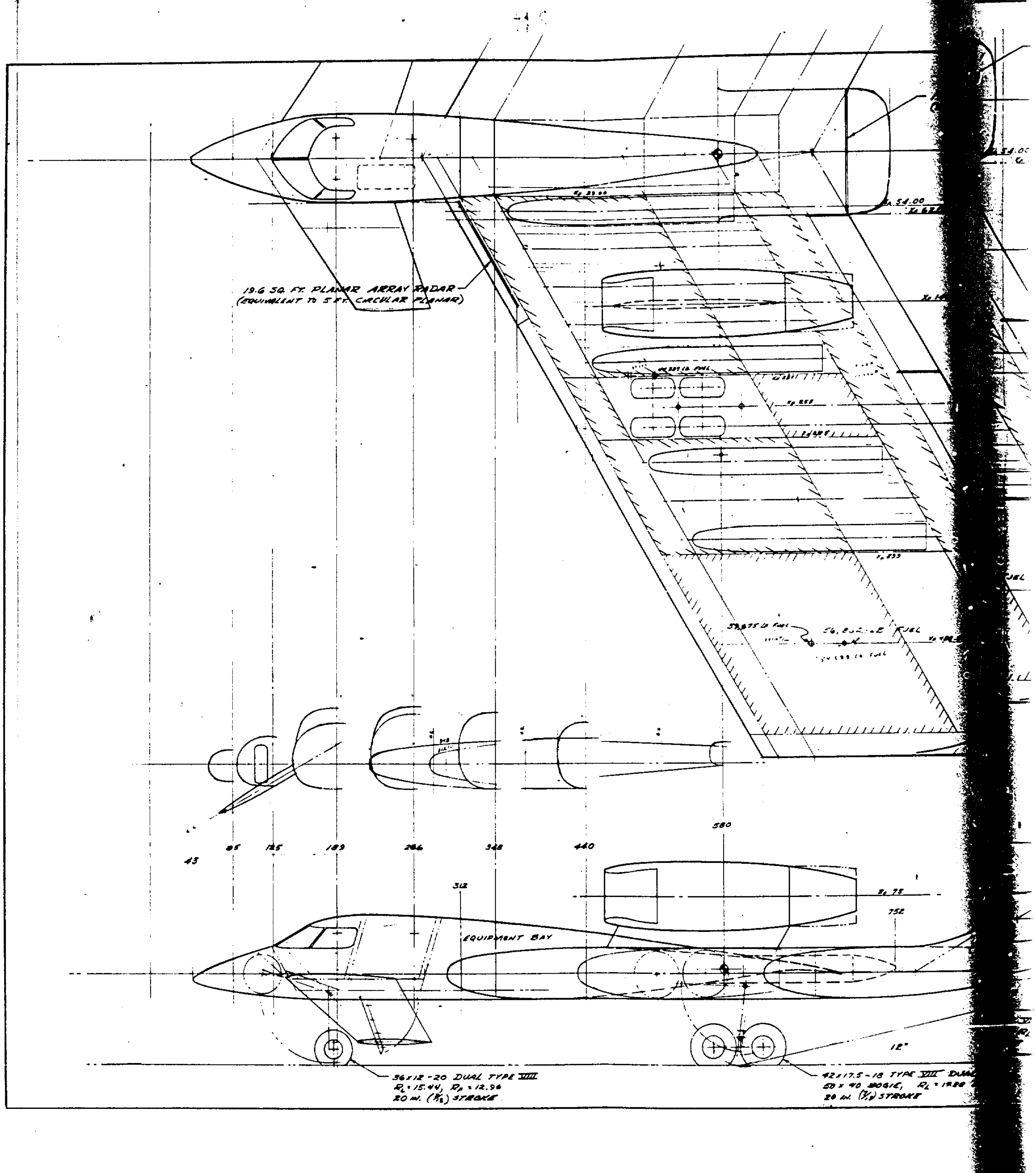
The following advanced technologies are employed:

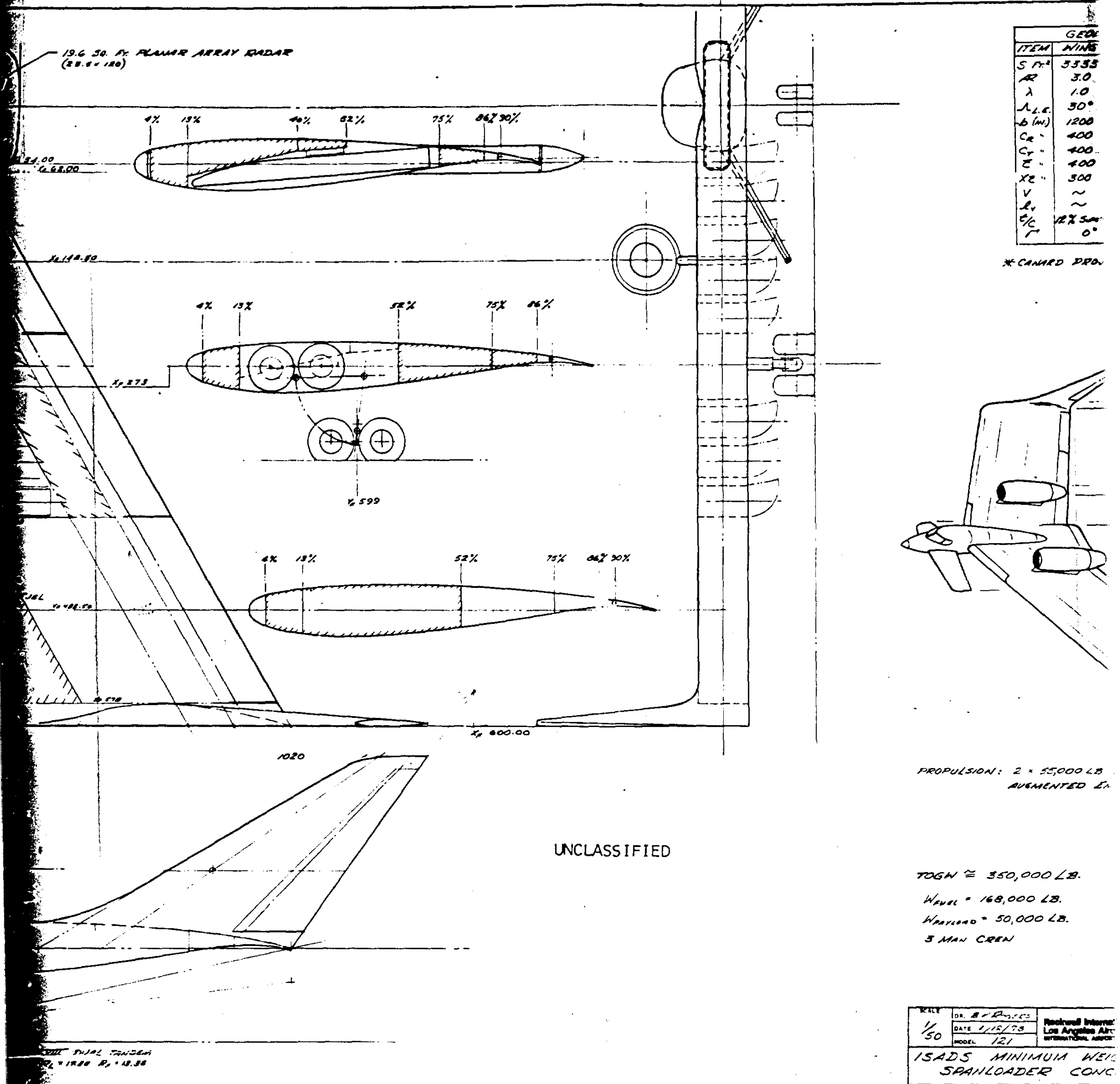
1. Supercritical wing

2. Aerodynamic surface coatings

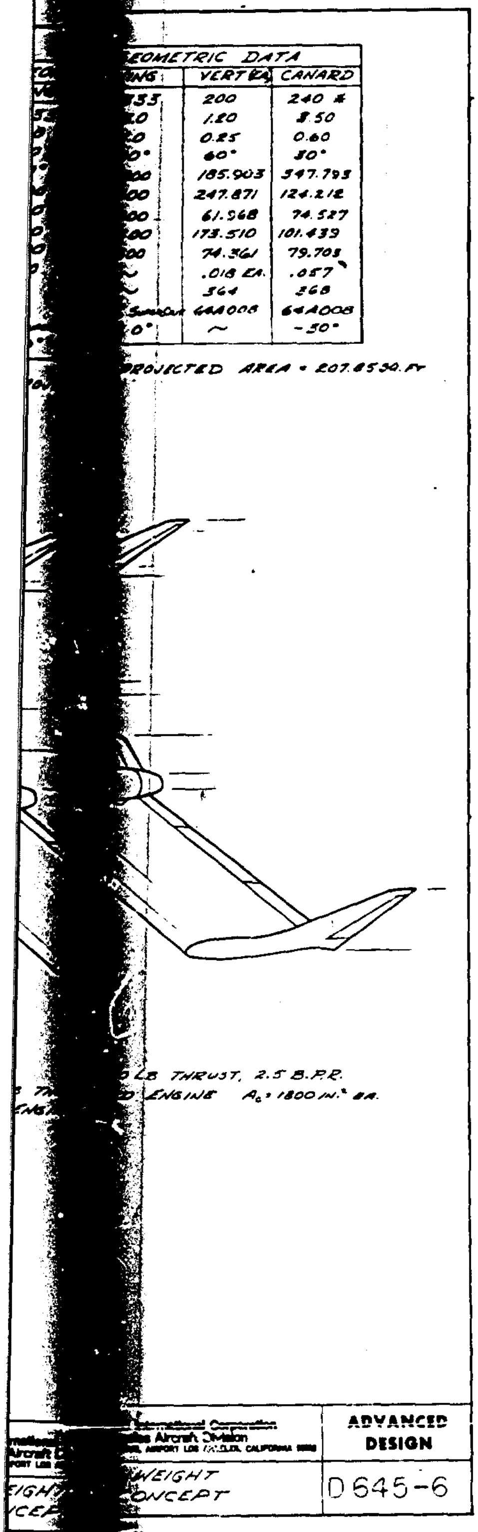
UNCLASSIFIED

(U) Figure 78. Minimum weight. (U)

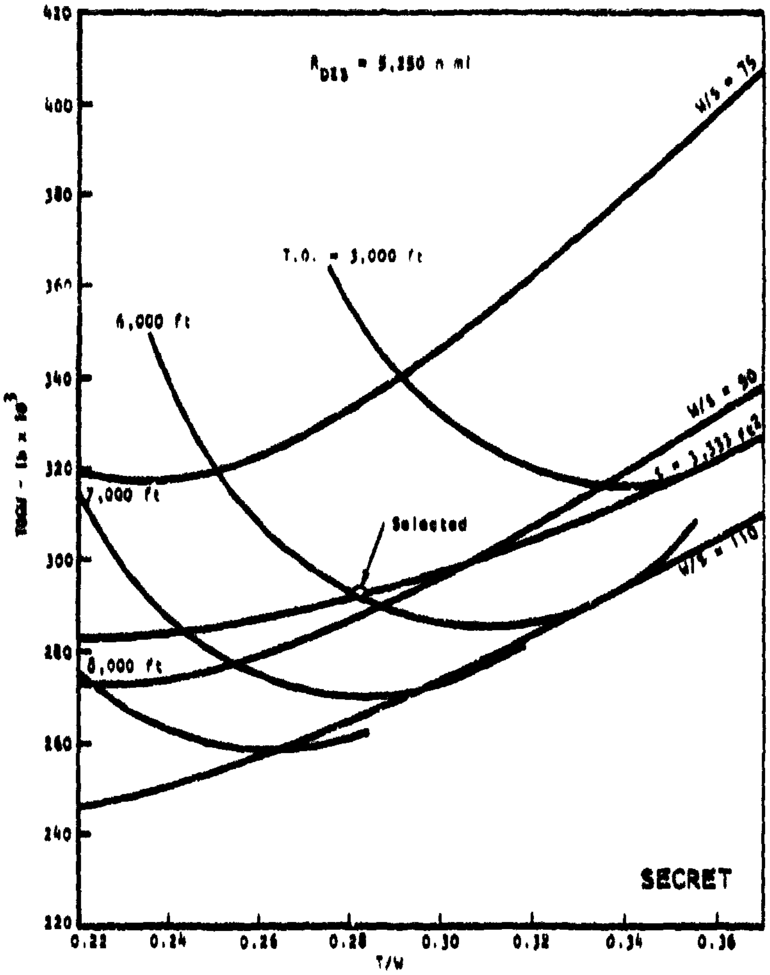

19.6 SQ. FT. PLANAR ARRAY RADAR
(EQUIVALENT TO 5 FT. CIRCULAR PLANAR)
43
85
125
189
266
348
440
580
312
752
EQUIPMENT BAY
12°
36x12-20 DUAL TYPE VIII
20 IN. STROKE



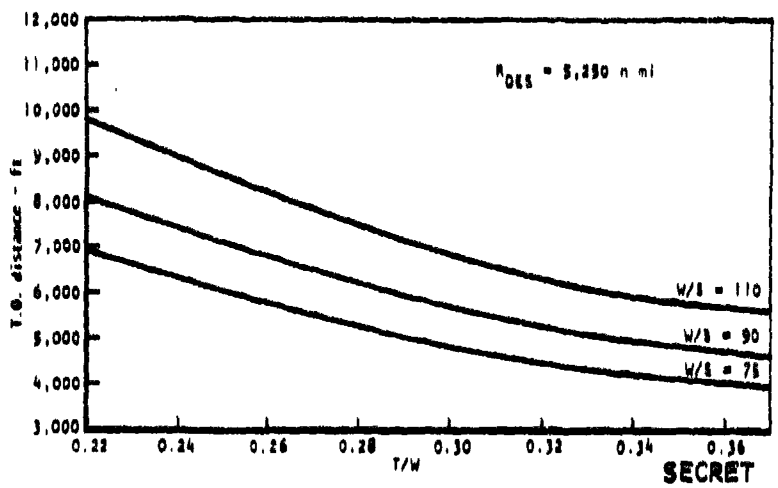
(U) Figure 79. ISADS - Minimum weight span loader



r co... der concept. (U)



(S) Figure 80. Minimum-weight design chart. (U)



(S) Figure 81. Minimum-weight take-off distance. (U)

3. Canard trimmer

4. Winglets

5. Composite wing boxes

6. SPF/DB titanium nacelles

7. Relaxed static stability, fly-by-wire (U)

(U) Performance and sizing charts for the minimum-weight concept are presented in Figures 80 and 81. The selected baseline airplane was chosen as having T/Wo = 0.282, Wo/S = 87.78 psf, and Wo = 292,570 lb. This selection was influenced by the requirement that wing area be no less than the "as-drawn" area of 3,333 square feet needed to carry the payload within the wing. If that requirement could be ignored (i.e., if the bombers were smaller) both W/S and T/W would be increased.

(U) A summary of airplane characteristics and performance for the selected minimum-weight concept is presented in Table 18. Mission summaries for the strategic (design) mission as well as theater and standoff missions are presented in Tables 19 through 21.

(S) TABLE 18. SELECTED MINIMUM-WEIGHT CONCEPT CHARACTERISTICS (U)

Takeoff gross weight, lb	292,570
Fuel weight, lb	150,818
Wing loading, psf	87.78
Thrust-to-weight	.282
Wing area, sq ft	3,333
Wing aspect ratio	3
Engine size	.687
Strategic mission range, n mi	5,250
Theater mission radius, n mi	3,034
Standoff mission patrol time, min	339
Takeoff distance, ft	5,971

SECRET

(U) Results of sensitivity trades for the mission weight concept are presented in Figures 82 through 84. These trades were performed about the baseline airplane as selected in the preceding. Takeoff distance requirement trades are presented both with and without the requirement that wing area be no less than 3,333 square feet.

(S) TABLE 19. STRATEGIC MISSION SUMMARY FOR SELECTED MINIMUM-WEIGHT CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n mi)	Total range (n mi)
Initial weight	292,570						
Warmup & T.O.	290,088	0	0.644	2,482	5.00	0	0
Climb	283,026	28,573	.850	7,062	18.58	146.1	146.1
Cruise	218,054	34,265	.850	64,972	343.91	2,853.9	3,000.0
Penetrate	179,791	200	.720	38,263	126.17	1,000.8	4,000.8
Drop	129,791	200	.720	0	0	0	4,000.8
Withdraw	109,241	200	.500	20,550	136.26	750.6	4,751.4
Climb	105,553	49,399	.850	3,687	16.78	130.4	4,882.8
Cruise	101,701	50,189	.850	3,853	43.49	369.6	5,252.4
Loiter	99,294	0	.278	2,407	30.00	0	5,252.4
Reserve	91,752	0	0	7,542	0	0	5,252.4
Total fuel = 150,818 lb							

SECRET

(S) TABLE 20. THEATER MISSION SUMMARY FOR SELECTED MINIMUM-WEIGHT CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n mi)	Total range (n mi)
Initial weight	292,570						
Warmup & T.O.	290,088	0	0.644	2,482	5.00	0	0
Climb	283,026	28,573	.850	7,062	18.58	146.1	146.1
Cruise	199,999	36,072	.850	83,027	458.33	3,788.1	3,934.2
Drop	149,999	42,083	.850	0	0	0	3,934.2
Cruise	101,695	50,199	.850	48,303	484.18	3,934.2	7,868.4
Loiter	99,288	0	.278	2,407	30.00	0	7,868.4
Reserve	91,752	0	0	7,536	0	0	7,868.4
Total fuel = 150,818 lb							

SECRET

(S) TABLE 21. STANDOFF MISSION SUMMARY FOR SELECTED MINIMUM-WEIGHT CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n mi)	Total range (n mi)
Initial weight	292,570						
Warmup & T.O.	290,088	0	0.644	2,482	5.00	0	0
Climb	283,026	28,573	.850	7,062	18.58	146.1	146.1
Cruise	228,335	33,262	.850	54,691	203.03	2,353.9	2,500.0
Patrol	181,978	19,979	.558	46,358	338.99	0	2,500.0
Drop	131,978	19,970	.558	0	0	0	2,500.0
Climb	129,136	48,186	.850	2,842	13.68	108.4	2,608.4
Cruise	101,707	50,190	.850	27,428	204.33	2,391.6	5,000.0
Loiter	99,300	0	.278	2,407	30.00		5,000.0
Reserve	91,752	0	0	7,548	0		5,000.0
Total fuel = 150,818 lb							

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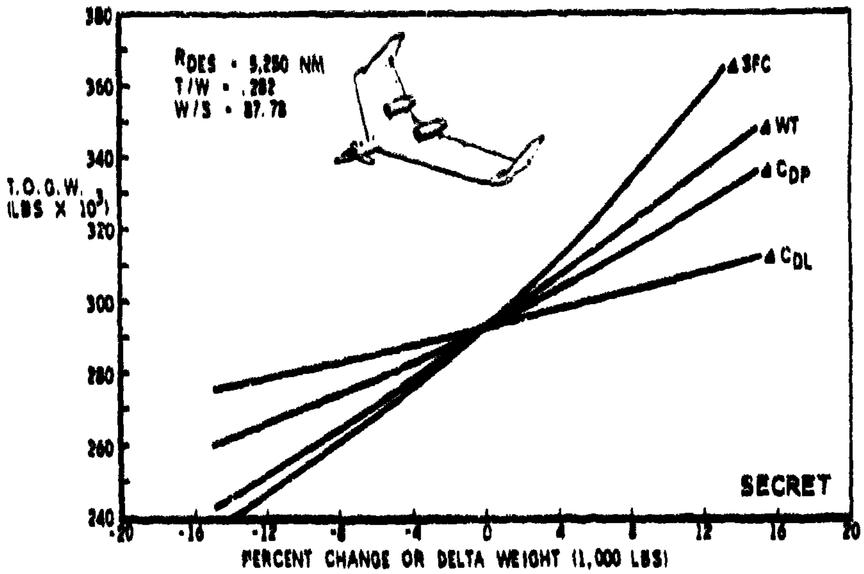
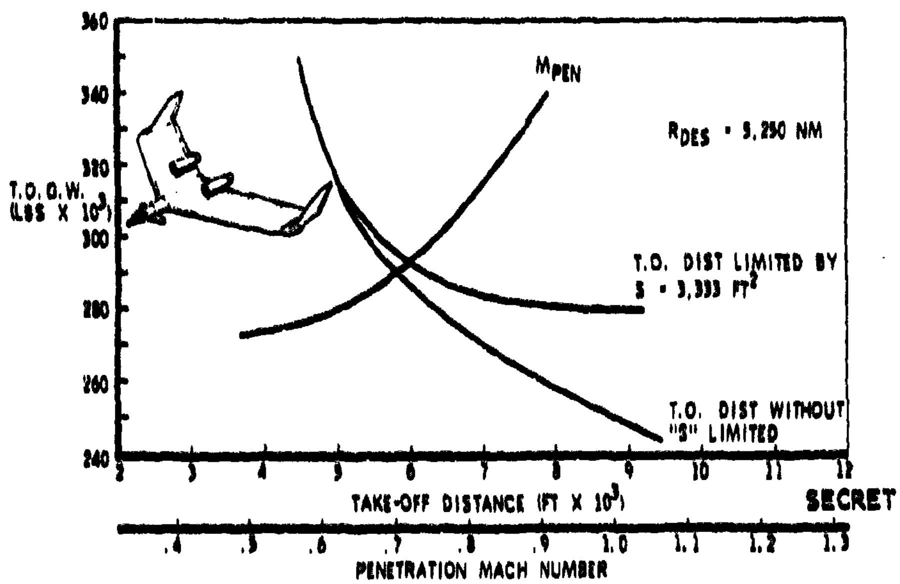
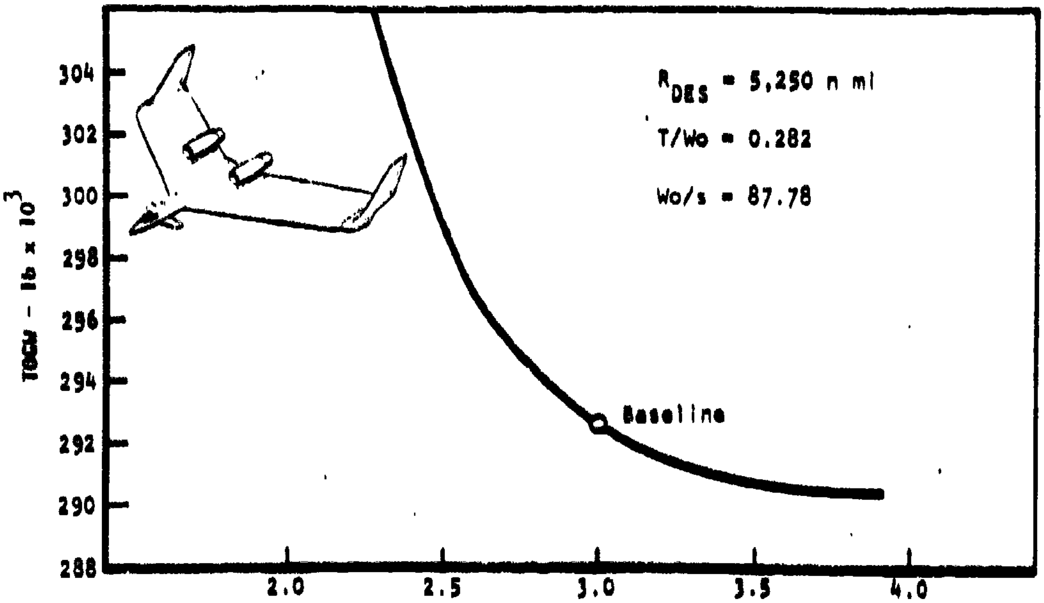


(S) Figure 82. Minimum-weight concept design sensitivities.(U)



(S) Figure 83. Minimum-weight concept mission sensitivities.(U)



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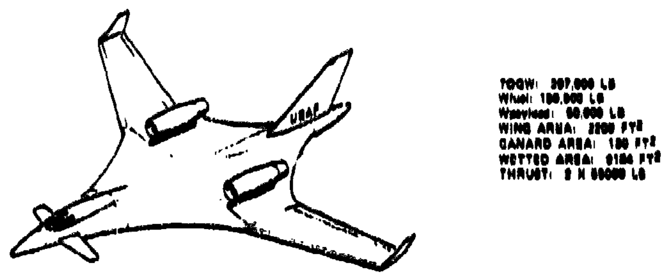
(U) Figure 84. Minimum-weight aspect ratio trade. (U)

(U) Minimum-Weight Concept Design Trades (U)

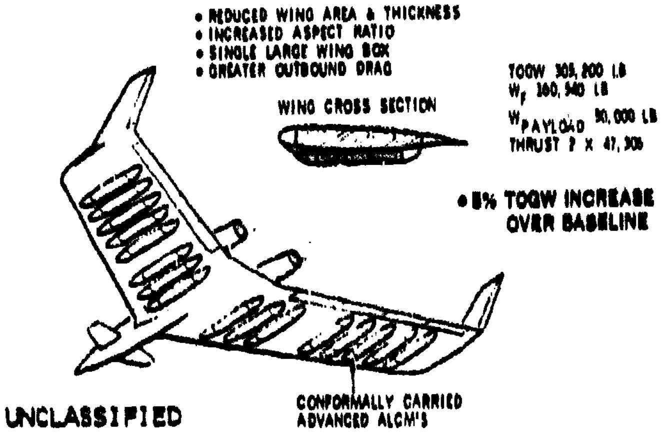


- BLENDED WING/BODY
- UPPER NACELLES FOR FAVORABLE PRESSURE EFFECTS
- COMPOSITE PRIMARY STRUCTURE
- SHAPE DRIVEN BY ROTARY LAUNCHER REQUIREMENT

UNCLASSIFIED

(U) Figure 85. Minimum-weight baseline with rotary launchers. (U)

(U) The first trade study on the minimum-weight concept dealt with the rotary launcher requirement. Figure 85 shows this concept as originally drawn with two rotary launchers. This concentrated the payload, eliminating the spanloader advantage, and resulted in a very high takeoff gross weight. It was decided in cooperation with the Air Force ISADS program manager to relax this requirement for the minimum-weight category, which resulted in the span-loaded baseline previously shown.



(U) Figure 86. Conformal weapons carriage. (U)

(U) As previously mentioned, internal carriage of payload in spanloader concepts forces the wing twisting moments into two small boxes rather than a single, more efficient large box. A trade was therefore conducted in which the weapons were carried externally, leaving a single, unbroken wing box (Figure 86). This reduced the structural weight, but the increased drag of the external weapons yielded a net weight increase.

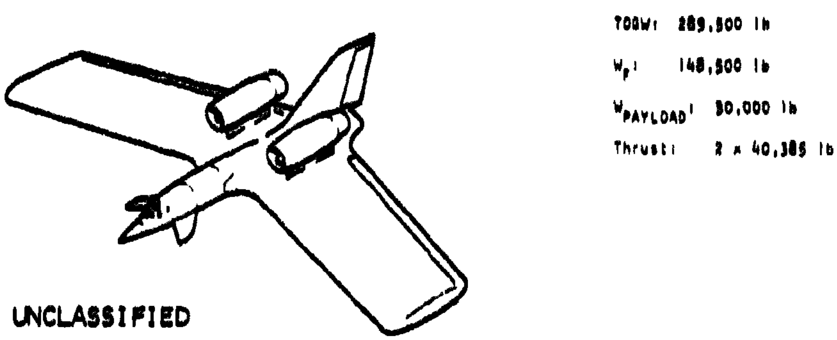
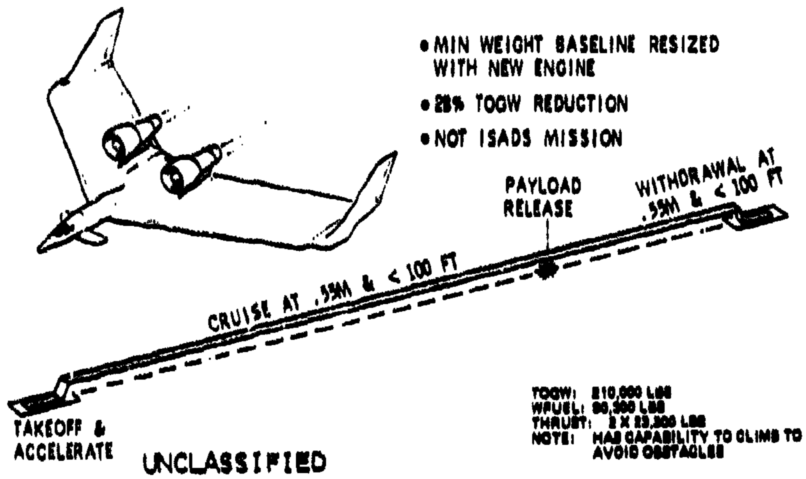


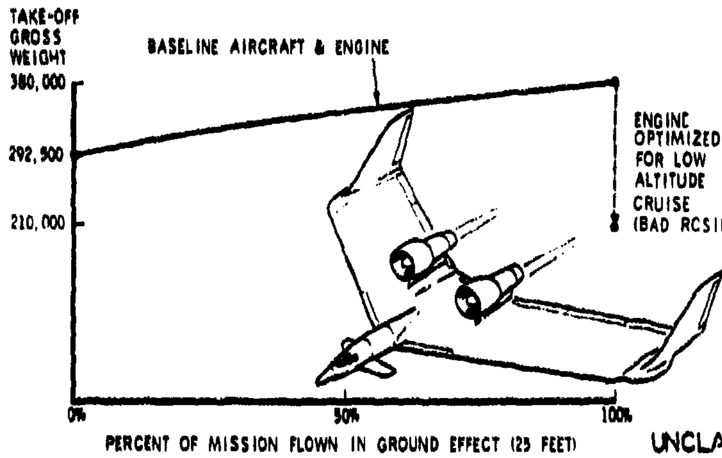
Figure 87. Forward sweep design trade.

(U) Since the forward-swept, constant-chord wing proved successful in the low-cost category, it was applied to the spanloader concept (Figure 87). Some reduction was obtained, but it was partially canceled by the loss of the winglets, which had to be moved inboard to retain the required tail volume.



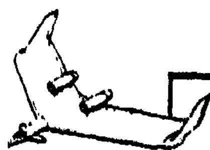
(U) Figure 88. Ground effect. (U)

(U) A further trade was conducted by the application of ground effect. A 25-foot altitude (RMS), mach 0.55 mission was postulated (Figure 88), and the minimum-weight baseline was reengined and resized. This produced the extremely low takeoff gross weight of 210,000 pounds, but, of course, not for the ISADS high-low-low-high mission. It was then imagined that the partial use of ground effect could produce some proportional savings. This would allow the aircraft to use ground effect over flat portions of its mission, but rising up for cruise over nonflat areas. However, the optimal engine for a high-low-low-high mission is very poor at mach 0.55 and 25 feet; therefore, weight actually rose with ground effect usages. This is shown in Figure 89, along with the effect of reengining a 100-percent ground effect aircraft. Mission studies are recommended to determine if the ground effect concept can be applied to a strategic penetrator.



UNCLASSIFIED

(U) Figure 89. Impact of occasional ground effect usage. (U)



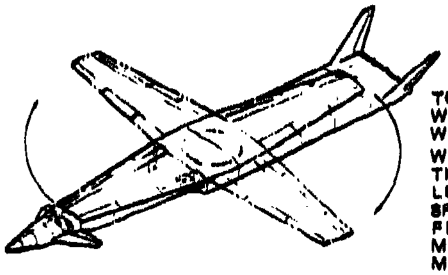
	BASELINE	ACTIVE LAMINAR FLOW SUCTION	VCE
TOGW/LBS	292,570	271,760	284,000
WFUEL/LBS	150,818	123,660	146,000
WPAYLOAD	50,000	50,000	50,000
THRUST	2 X 41,252	2 X 36,280	2 X 39,900

UNCLASSIFIED

(U) Figure 90. Other design trades minimum weight. (U)

(U) Figure 90 summarizes other design trades which were applied to the minimum weight baseline. The most interesting of these is active laminar flow suction. Despite a 10,000-pound deadweight penalty for the ducts and pumps, this trade yielded the substantial savings of 21,000 pounds, due to greatly reduced skin friction drag. This does involve a high technical risk at the present time, primarily due to ingestion, but should be pursued further.

(U) The same variable-cycle trade mentioned in the low-cost trades was applied to the minimum-weight concept. This produced an 8,000-pound savings, which is appreciable, but probably not worth the complexity of a variable-cycle engine.



TOGW: 551,880 LBS
WFUEL: 325,421 LBS
WPAYLOAD: 50,000 LBS
WING AREA 2,759 FT²
THRUST: 4 X 41,3[illegible]
LENGTH: 167.4 F[illegible]
SPAN: 125.6 FT
FLYAWAY COST: $52.9 MILLION
MISSION II RADIUS: 4,507 N. MI
MISSION III LOITER: 533.2 MINUTES

- HIGH ASPECT RATIO FULLY SKEWABLE WING
- FLIES ON BODY LIFT AT HIGH SPEEDS
- MULTIPLE CYCLE ENGINES
- SUPINE COCKPITS FOR 'G' & VIBRATION TOLERANCE

SECRET

(S) Figure 91. Minimum penetration time baseline. (U)

MINIMUM PENETRATION TIME BASELINE

(C) Figure 91 summarizes the minimum penetration time baseline. This concept is based on the fact that at supersonic speeds on the deck, most of the aircraft drag is due to skin friction or wetted area drag. This concept minimizes wetted area at high speeds by completely hiding the wing and riding on supersonic body lift.

(U) Control is provided by a canard, a V-tail, and four 2-D nozzles. An advanced fly-by-wire system is assumed. Supine cockpits minimize drag while increasing pilot G-tolerance.

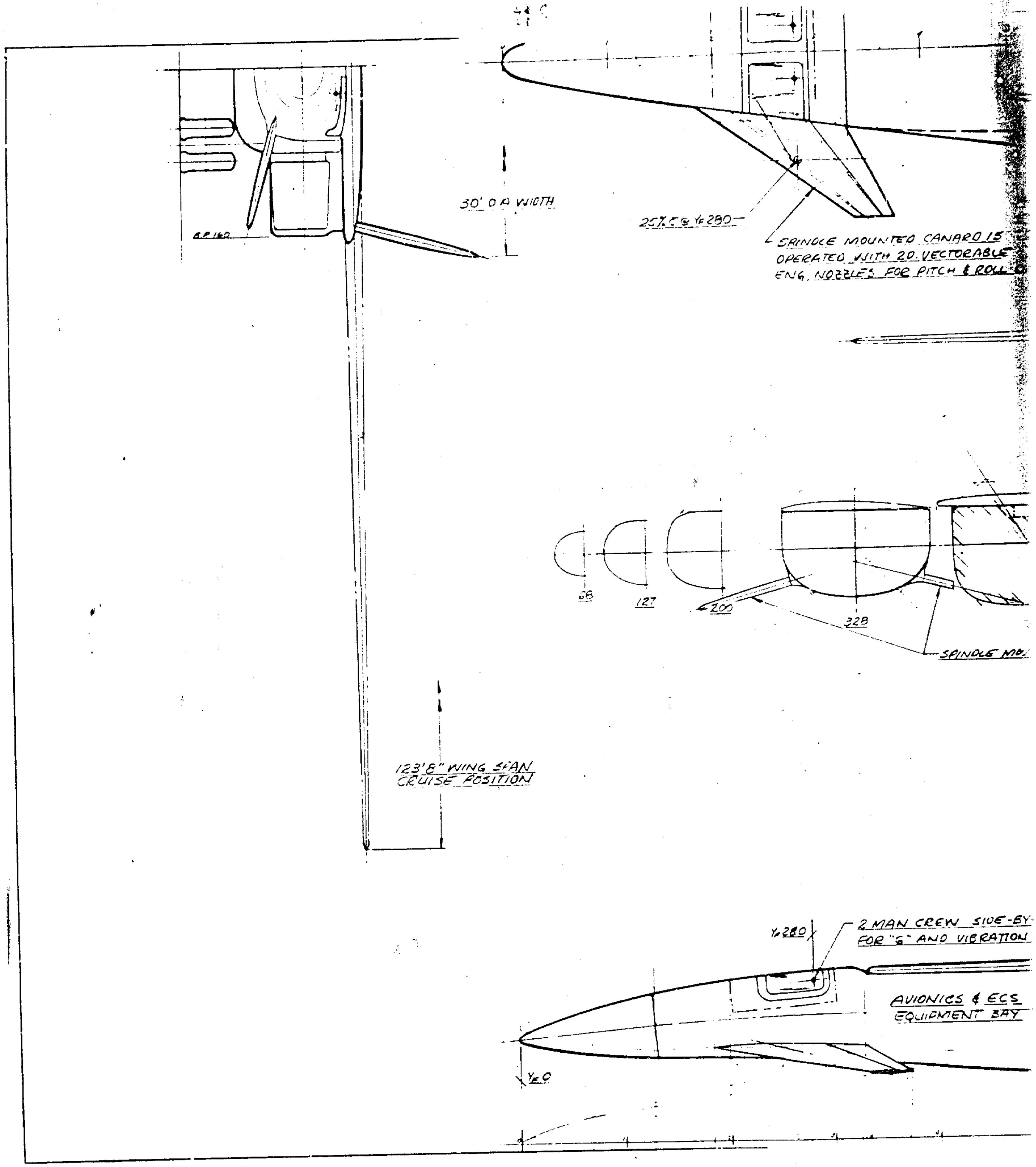
(U) Four engines are required to obtain the required thrust level. These are advanced variable/multiple-cycle engines. (Refer to "Minimum Penetration Time Design Trades.")

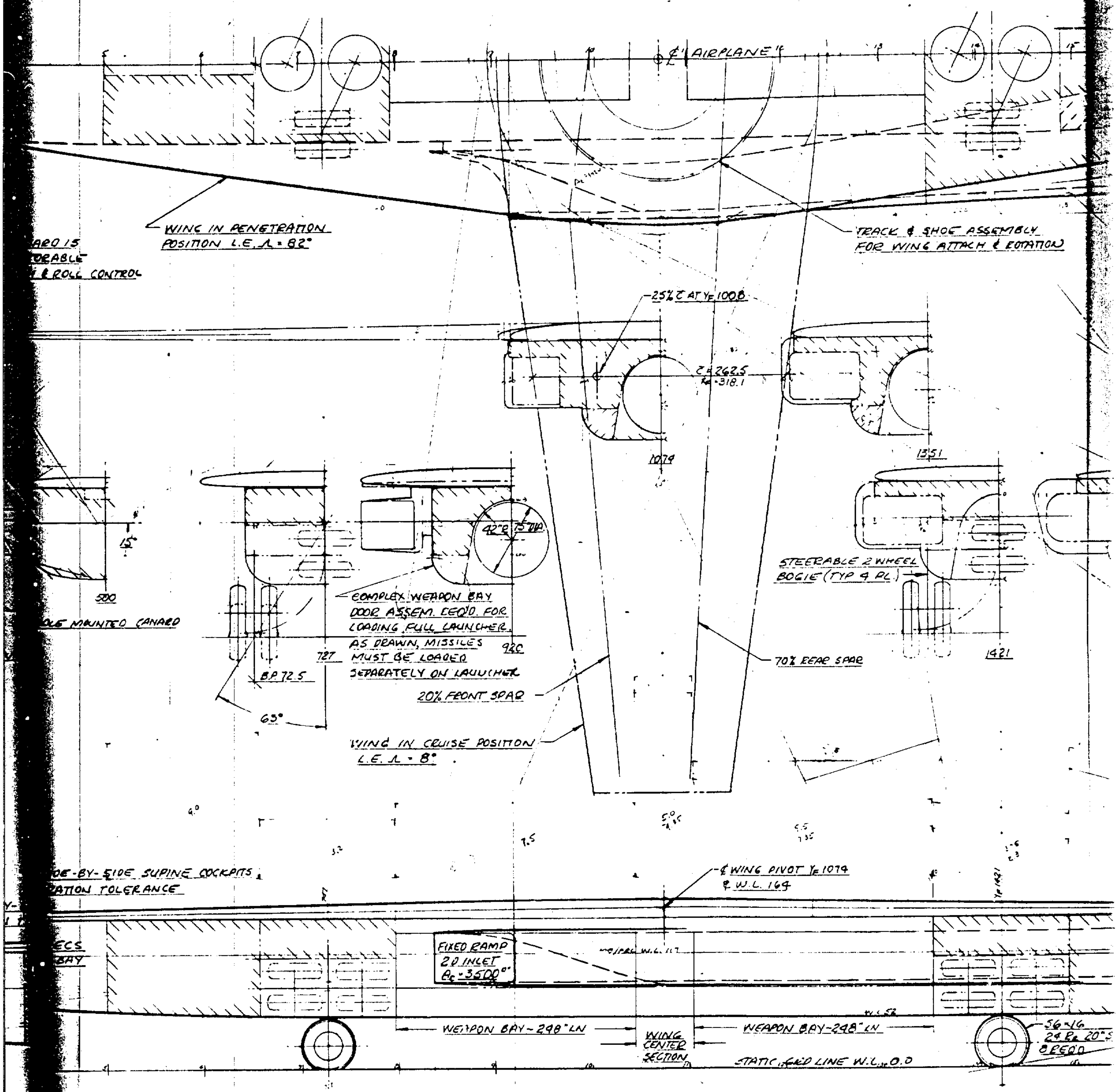
The following advanced technologies are employed:

1. Surface coatings
2. Variable-skew wing
3. Variable/multiple-cycle engine
4. 2-D vectorable nozzles
5. SPF/DB titanium
6. Fly-by-wire, integrated propulsion controls

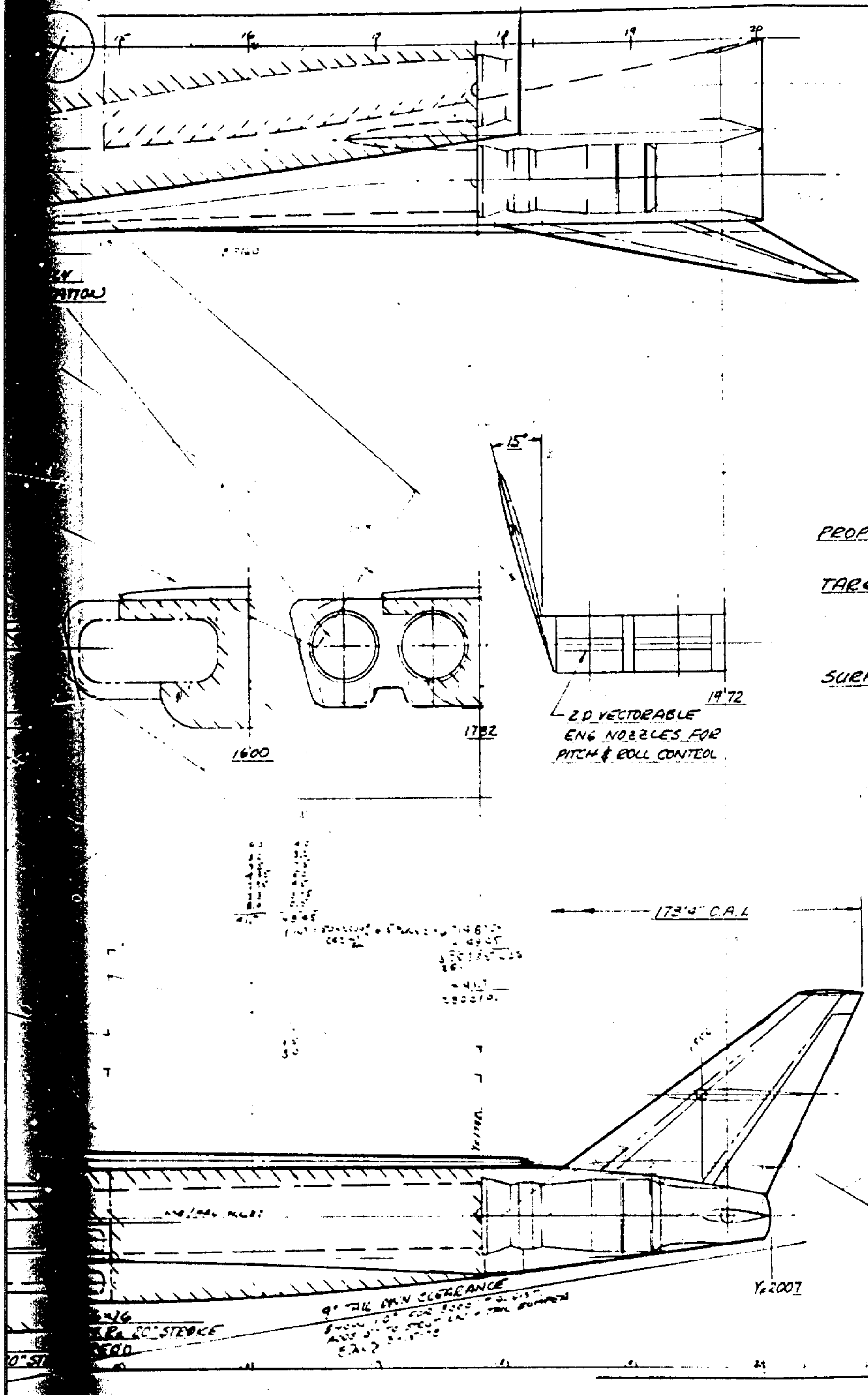
UNCLASSIFIED

(U) Figure 92. Minimum penetration time. (U)


30' 0 A WIDTH
B.P.160
25% C @ Y 280
SPINDLE MOUNTED CANARD IS
OPERATED WITH 2D VECTORABLE
ENG. NOZZLES FOR PITCH & ROLL
68
127
200
328
SPINDLE
123'8" WING SPAN
CRUISE POSITION
Y 280
2 MAN CREW SIDE-BY-
FOR "G" AND VIBRATION
AVIONICS & ECS
EQUIPMENT BAY
Y 0



℄ AIRPLANE
WING IN PENETRATION POSITION L.E. Λ = 82°
TRACK & SHOE ASSEMBLY FOR WING ATTACH & ROTATION
ROLL CONTROL
25% C̄ AT Y_F 1008
C̄ = 262.5
1074
1351
15°
500
42"D
75 DIA
COMPLEX WEAPON BAY DOOR ASSEM. REQ'D. FOR LOADING FULL LAUNCHER. AS DRAWN, MISSILES MUST BE LOADED SEPARATELY ON LAUNCHER
727
920
BP 72.5
63°
20% FRONT SPAR
70% REAR SPAR
STEERABLE 2 WHEEL BOGIE (TYP 4 PL.)
1421
WING IN CRUISE POSITION L.E. Λ = 8°
SIDE-BY-SIDE SUPINE COCKPITS
TOLERANCE
℄ WING PIVOT Y_F 1074
℄ W.L. 164
ECS
BAY
FIXED RAMP
2D INLET
A_c = 3500□"
WEAPON BAY ~ 248" LN
WING CENTER SECTION
STATIC GRD LINE W.L. 0.0



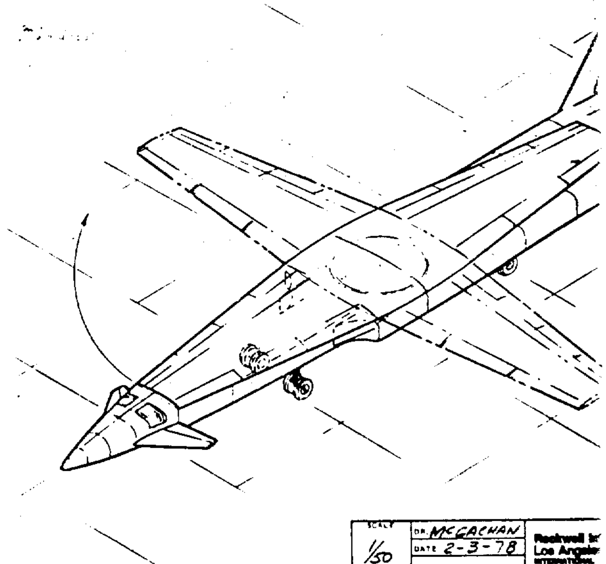
ITEM		WING	CANARD	VER…
S	FT²	2550	100	
AR		6.0	2.4	
λ		0.4	0.3	
$\Lambda_{L.E.}$		8°	55°	
b	IN.	1484.3	185.9	
C_R	IN.	353.4	119.2	
C_T	IN.	191.4	35.7	
$\bar{c}$	IN.	262.5	84.9	
$\bar{c}_{X_0 \to \bar{c}_r}$		318.1	38.1	
V		——	0.11	
ℓ_V	IN.	——	728	
t/c		6%	6%	

GEOMETRIC DATA

PROPULSION: FOUR 53,000 LB S.L.S. THRUST ENGINES WITH 2D …
A_I = 3420 Sq. IN. PER SIDE., A_E = 1800 Sq. IN. EA…

TARGET WEIGHTS:
T.O.G.W. = 510,000 LBS
WT_{FUEL} = 250,000 LBS FUS. TANKS (NO WING F…
$WT_{PAYLOAD}$ = 50,000 LBS

SURFACE AREA:
PENETRATION - WING ROTATED = 9168 FT²
CRUISE ~ WING NORMAL = 12,310 FT²



SCALE 1/50 | DR. MCGACHAN | DATE 2-3-78 | MODEL | Rockwell In… Los Angele… International
15ADS ~ MINIMUM P… TIME BASELINE C…

UNCLASSIFIED

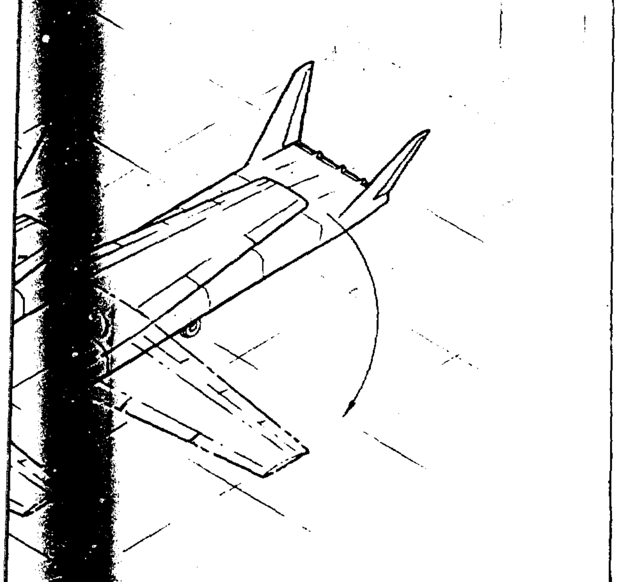
(U) Figure 93. Minimum penetration time basel…

...RIC DATA		
	CANARD	VERTI?AL EA.
	100	100
	2.4	1.2
	0.3	0.3
	55°	55°
	185.9	131.5
	119.2	168.5
	35.7	50.6
	84.9	120.1
	38.1	53.9
	0.11	0.5 TOTAL
	728	944
	6%	6%

...NGINES WITH 2D VECTORABLE NOZZLES
...• 1800 SQ.IN. EA. NOZZLE IN A/B.

...TANKS (NO WING FUEL)

...168 FT²
...310 FT²



MCGACHAN 2-3-78	Rockwell International Corporation Los Angeles Aircraft Division	ADVANCED DESIGN
...S ~ MINIMUM PENETRATION ... BASELINE CONFIGURATION		D645-3

D645-3

...on time baseline configuration. (U)

3

4

(U) Performance and sizing charts for the minimum time penetrator concept are presented in Figures 94 and 95. The selected baseline airplane was chosen as having T/Wo = 0.30, Wo/S = 200 psf, and Wo = 551,880 lb.

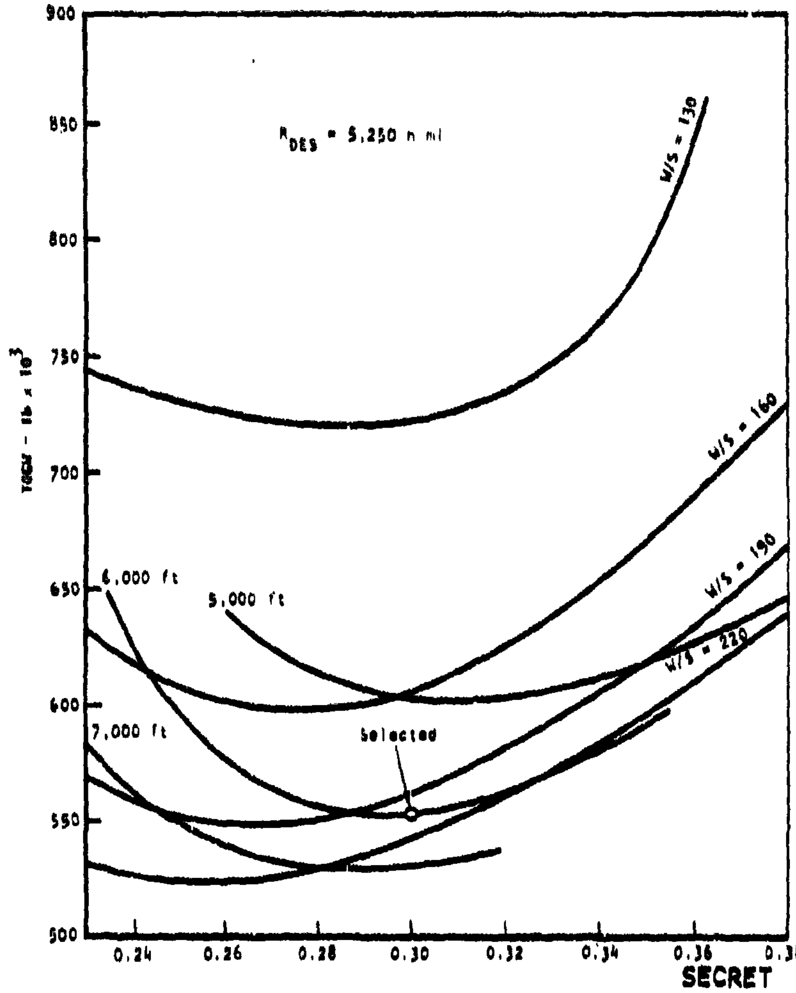
(S) TABLE 22. SELECTED HIGH "Q" PENETRATOR CONCEPT CHARACTERISTICS (U)

Takeoff gross weight, lb	551,880
Fuel weight, lb	328,121
Wing loading, psf	200
Thrust-to-weight	.30
Wing area, sq ft	2,759
Wing aspect ratio	6.0
Engine size	.821
Strategic mission range, n mi	5,250
Theater mission radius, n mi	1,600*
Standoff mission patrol time, min	333
Takeoff distance, ft	6,00[illegible]

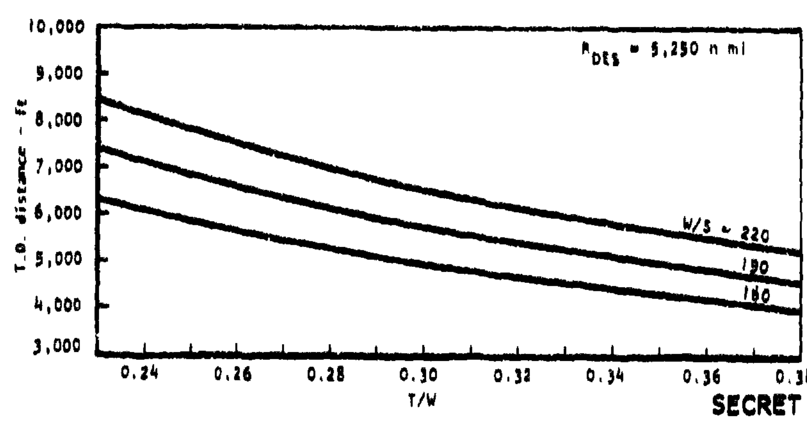
SECRET

(U) A summary of airplane characteristics and performance for the selected minimum time penetrator concept is presented in Table 22. Mission summaries for the strategic (design) mission as well as theater and standoff missions are presented in Tables 23 through 25.

(U) Results of sensitivity trades for this concept are presented in Figures 96 through 99. These trades were performed about the baseline airplane as selected in the preceding.



(S) Figure 94. High "Q" penetrator design chart. (U)



(S) Figure 95. High "Q" penetrator take-off distance. (U)

(S) TABLE 23. STRATEGIC MISSION SUMMARY FOR SELECTED HIGH "Q" PENETRATOR CONCEPT (U)

Leg Description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n mi)	Total range (n mi)
Initial weight	551,880						
Warmup & T.O.	546,891	0	0.788	4,989	5.00	0	0
Climb	541,481	20,010	.814	5,410	5.24	44.2	44.2
Cruise	[illegible]	[illegible]	.814	[illegible]	550.11	[illegible]	[illegible]
Penetrate	[illegible]	500	1.200	[illegible]	[illegible]	1,000.	4,000.
Drop	215,045	200	1.200	0	0	0	4,000.0
Withdraw	210,558	200	.755	[illegible]	123.30	750.2	4,750.2
Climb	206,125	11,150	.812	[illegible]	[illegible]	[illegible]	[illegible]
Cruise	197,505	32,050	.812	[illegible]	58.30	451.8	5,250.5
Loiter	192,733	0	.308	[illegible]	30.00	0	5,250.5
Reserve	176,150	0	0	16,271	0	0	5,250.5
Total fuel = 325,421 lb							

SECRET

(S) TABLE 24. STANDOFF MISSION SUMMARY FOR SELECTED HIGH "Q" PENETRATOR CONCEPT (U)

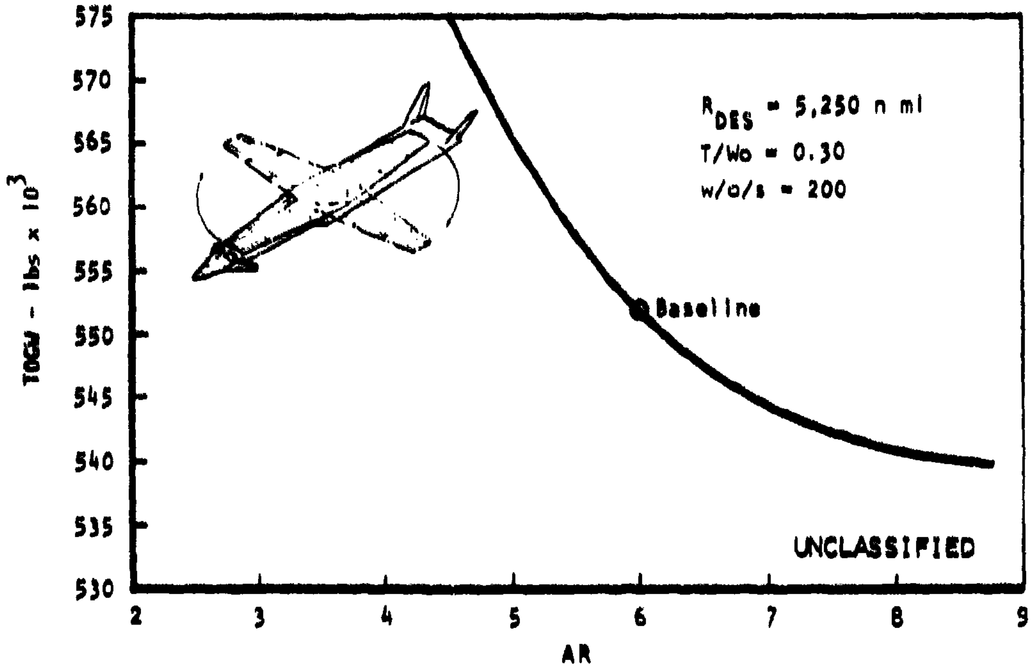
Leg Description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n mi)	Total range (n mi)
Initial weight	551,880						
Warmup & T.O.	546,891	0	0.788	4,989	5.00	0	0
Climb	541,481	20,010	.814	5,400	5.22	44.1	44.1
Cruise	433,305	31,020	.830	107,807	598.33	2,155.9	2,500.0
Patrol	303,120	20,022	.508	130,166	533.16	0	2,500.0
Drop	253,120	20,022	.508	0	0	0	2,500.0
Climb	250,743	30,746	.810	2,380	1.05	31.7	2,531.7
Cruise	197,417	42,088	.812	53,326	318.38	2,468.3	5,000.0
Loiter	192,754	0	.308	4,663	30.00	0	5,000.0
Reserve	176,150	0	0	16,205	0	0	5,000.0
Total fuel = 328,421 lb							

SECRET

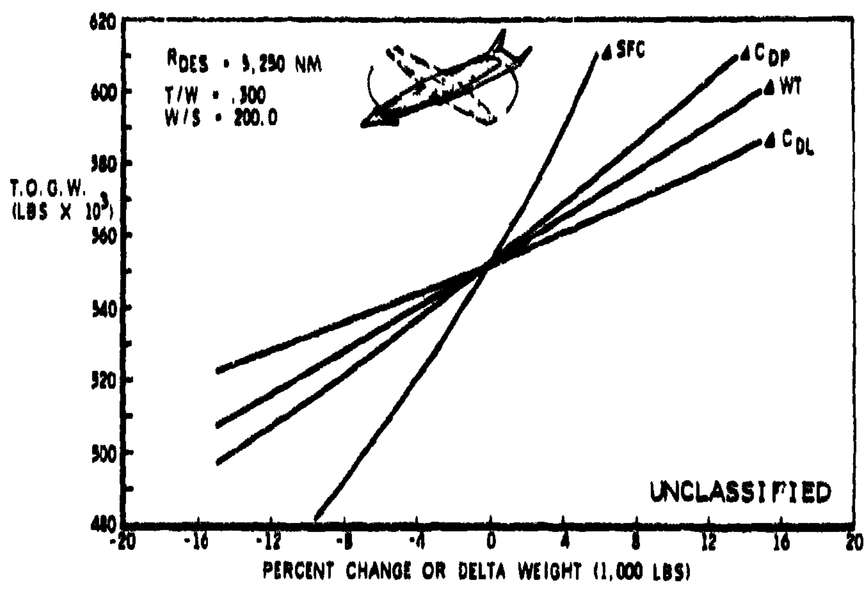
(S) TABLE 25. THEATER MISSION SUMMARY FOR SELECTED HIGH "Q" PENETRATOR CONCEPT (U)

Leg Description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n mi)	Total range (n mi)
Initial weight	551,880						
Warmup & T.O.	546,891	0	0.788	4,989	5.00	0	0
Climb	541,481	20,010	.814	5,410	5.24	44.2	44.2
Cruise	357,334	30,359	.830	184,147	883.77	4,562.6	4,606.8
Drop	307,334	30,359	.830	0	0	0	4,606.8
Cruise	197,411	42,036	.812	109,924	587.72	4,606.8	9,213.6
Loiter	192,748	0	.308	4,663	30.00	0	9,213.6
Reserve	176,459	0	0	16,289	0	0	9,213.6
Total fuel = 328,421 lb							

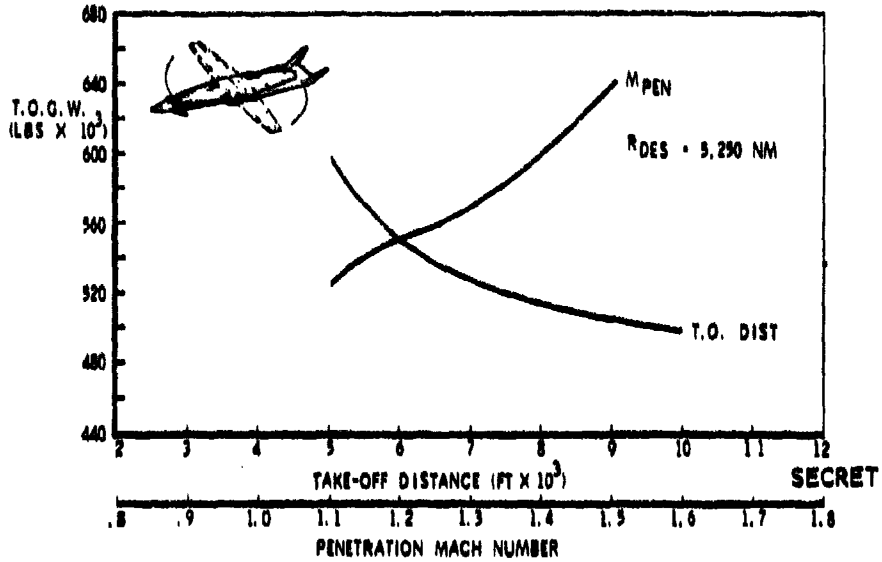
SECRET



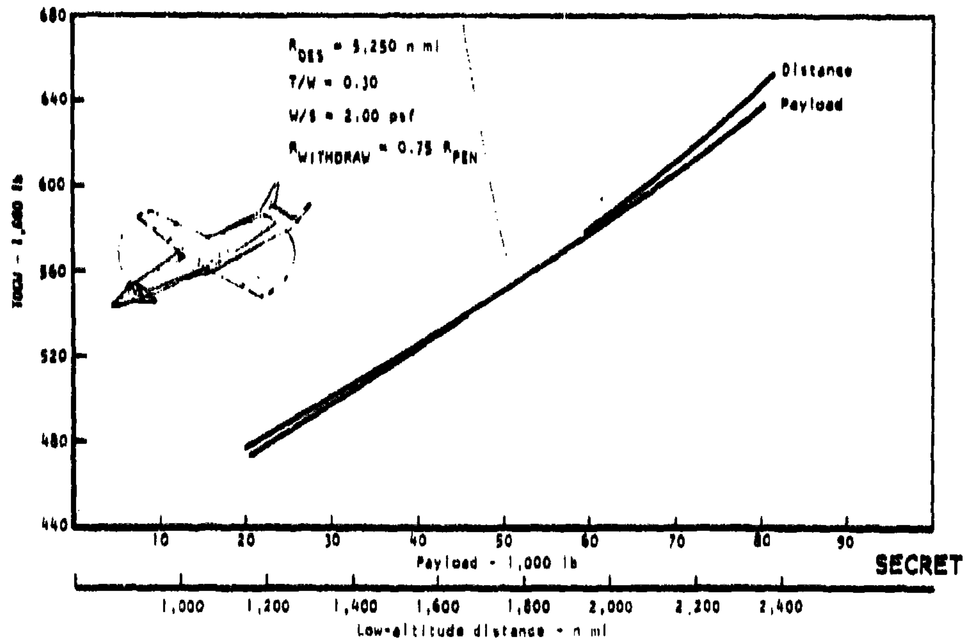
(U) Figure 96. High "Q" penetrator aspect ratio trade. (U)



(U) Figure 97. Minimum penetration time design sensitivities. (U)

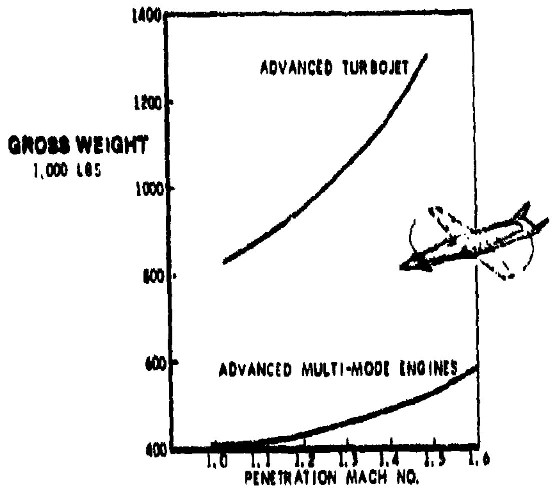


(S) Figure 98. Minimum penetration time mission sensitivities. (U)



(S) Figure 99. High "Q" penetrator concept payload and low-altitude distance trades. (U)

Minimum Penetration Time Design Trades



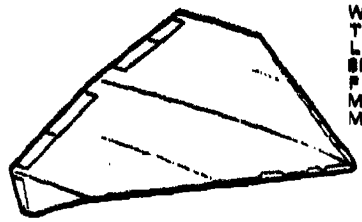
	BASELINE	ADVANCED FIXED CYCLE TURBOJET
TOGW	551,880	880,000
W_{FUEL}	325,421	519,700
$W_{PAYLOAD}$	50,000	50,000
THRUST	4 x 41,391	4 x 66,100 LB

SECRET

(S) Figure 100. Design trade minimum penetration time concept.(U)

(U) It was originally intended to use an advanced turbojet as the baseline engine for this concept, with a variable-cycle engine to be used as a trade study. However, the initial sizing exercise quickly revealed the impracticality of this approach (Figure 100). The turbojet aircraft weighs almost 9 million pounds, which is totally unacceptable. Therefore, a variable/multiple-cycle engine comparable to the engine discussed in the paragraphs on low-cost trades was employed on the baseline.

(U) Also, the Rockwell multimode integrated propulsion system (MMIPS) was examined for this aircraft. A MMIPS could provide SFC improvements of approximately 3 percent at subsonic cruise and at penetration relative to the VCE baseline. This would be achieved by using a fan engine with a higher bypass ratio, approximately 2.5, sized for subsonic cruise, and sizing the turbojet for takeoff and penetration. The MMIPS weight would be approximately the same as the VCE baseline because the significantly higher takeoff specific thrust of the MMIPS would allow smaller engines. While SFC is extremely important in the minimum time penetration aircraft, the modest improvement the MMIPS offers tends to be offset by the complexity of the installation. Thus, the MMIPS was not analyzed further.



TOGW: 302,396 LBS
WFUEL: 164,882 LBS
WPAYLOAD: 50,000 LBS
WING AREA: 3,287 FT2
THRUST: 2 X 49,896 LBS
LENGTH: 76.7 FT
SPAN: 81.1 FT
FLYAWAY COST: $31.8 MILLION
MISSION II RADIUS: 3,747 N. MI
MISSION III LOITER: 280.0 MINUTES

- NEARLY FLAT TOP PROVIDED BY SUPERCRITICAL AIRFOIL
- BURIED INLETS & DUCTS HIDE ENGINE FACES
- PLANAR-ARRAY FORWARD RADARS ELIMINATE RADOME

SECRET

(S) Figure 101. Stealth baseline. (U)

STEALTH BASELINE

(U) Figure 101 summarizes the stealth baseline. This concept features reduced radar, infrared, and visual observables.

(U) Radar cross section is reduced primarily by geometry. Extensive use of radar-absorbent material (RAM) is not required, since the featureless flat top reflects away any radar scanning from above. This flat top is provided by the use of a supercritical airfoil.

(U) The flat-wrap leading edge windshields are gold flashed to simulate the rest of the wing. This leading edge is swept back 45 degrees to reflect away any radar scanning from the forward hemisphere. Flush inlets with long, curved ducts totally hide the forward engine fact while a plug nozzle hides the aft engine face. Small ventral verticals use some RAM surface coatings to minimize intersection return.

(S) Infrared signature is reduced by a slow penetration speed (mach 0.72) and cooled plug nozzles.

(U) Visual signature is reduced by the lack of shadow-causing features and the extreme smallness of the concept. At 76.7 feet long, it is only half the size of the B-1. This is accomplished by the large internal volume available in a thick, supercritical flying delta wing.

(U) Figure 102. Stealthy. (U)

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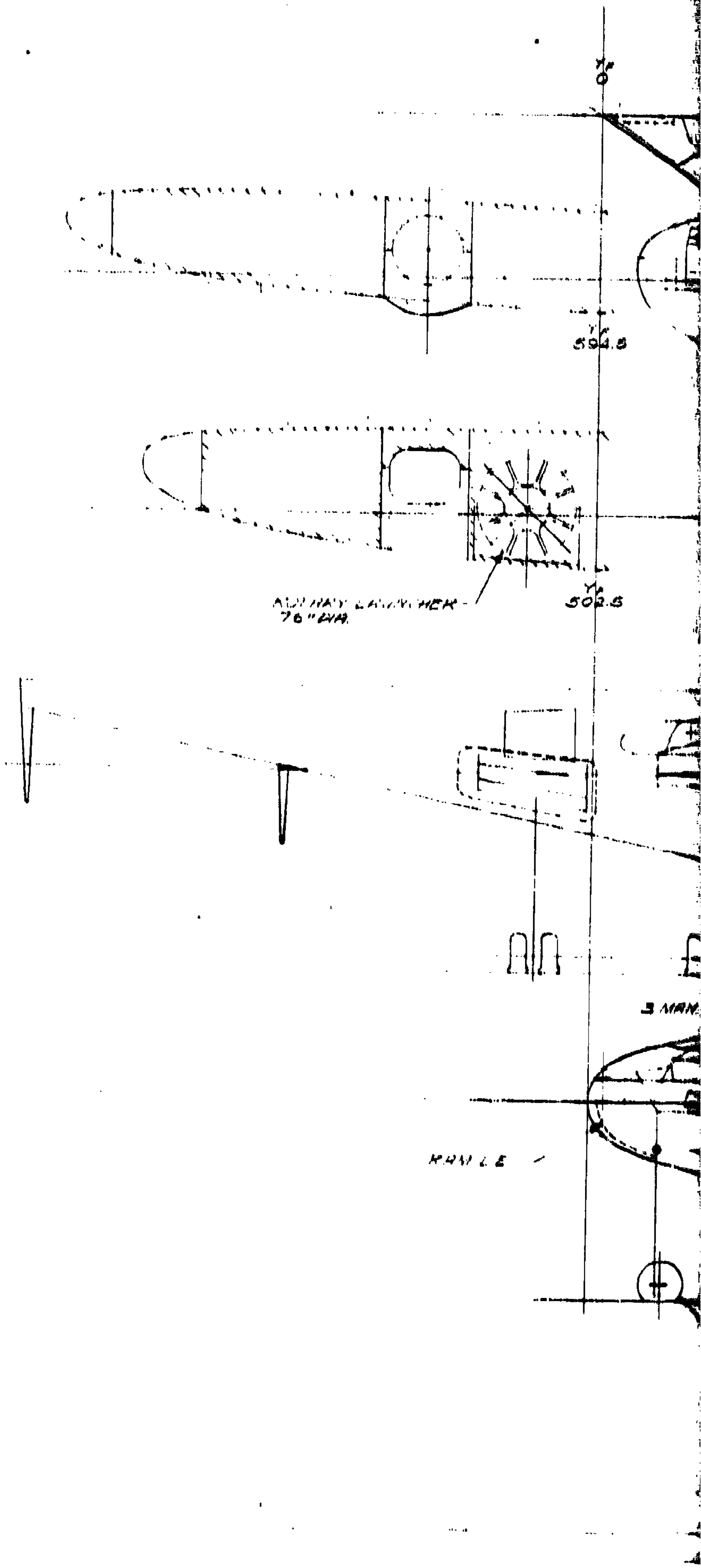
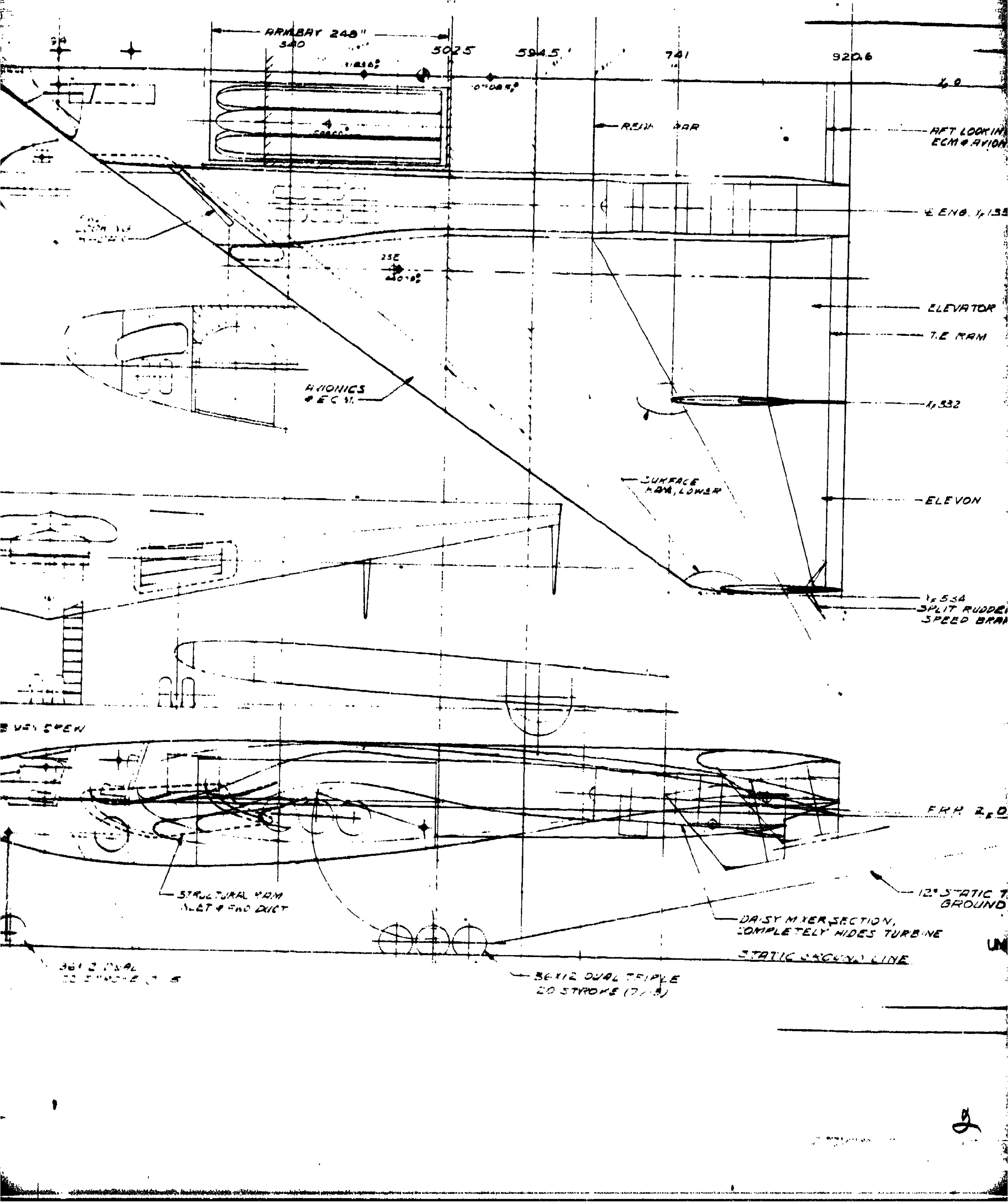
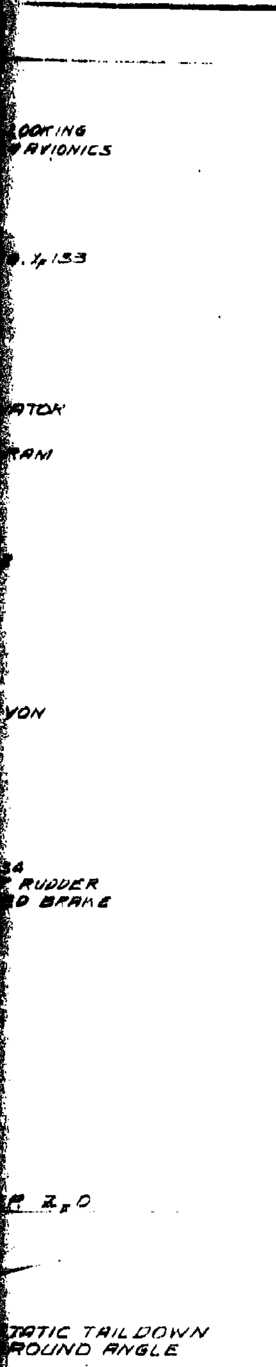

594.5
502.5



ARMBAY 248"
540
5025
594.5
741
920.6
REAR SPAR
AFT LOOKIN
ECM & AVION
ENG.
ELEVATOR
T.E RAM
ELEVON
SPLIT RUDDE
SPEED BRA
AVIONICS
SURFACE
RAM, LOWER
FRP
STRUCTURAL RAM
DAISY MIXER SECTION,
COMPLETELY HIDES TURBINE
STATIC GROUND LINE
36x12 DUAL TRIPLE
20 STROKE
12° STATIC
GROUND



GEOMETRIC DATA		
ITEM	WING	VERT TAIL
S	3960 FT²	50 FT² EACH
AR	2.0	.8
Ⓐ λ	.16	.5
Λ	55° (L.E.)	0° (T.E.)
b	89 FT	6.52 FT
C_R	920.6 IN	126.5 IN
C_T	147.5 IN	62.2 IN
$\bar{c}$	627.3 IN	98.4 IN
$\bar{Y}_{MAC}$	202.5 IN	33.7 IN
Γ	6°	—
Ⓐ AIRFOIL	14% S.C.	65A005

PROPULSION
TWO ADVANCED AUGMENTED TURBOFANS WITH DAISY MIXER SECTIONS AND TWO-DIMENSIONAL ALBEN NOZZLES
Ⓐ THRUST = 60000 LBS. EA., INSTALLED

WEIGHTS
TOGW = 412000 LBS.
FUEL = 183000 LBS
PAYLOAD = 50000 LBS
AVIONICS = 4800 LBS

60,000 WAS 6000
REVISED DRAWING - 14% WAS 10%, λ .16 WAS 1.6,
"A" CHANGE 1-18-78 D.W. DUNBAR

UNCLASSIFIED

SCALE 1/50	DR LAMB / DATE [illegible] / MODEL	Rockwell International Corporation, Los Angeles Aircraft Division, International Airport, Los Angeles, California	ADVANCED DESIGN
ISADS, STEALTH, BASELINE			D645-4A

D645-4A

(U) Figure 103. Stealth baseline. (U)

3

The following advanced technologies are employed:

1. Supercritical wing
2. Aerodynamic surface coatings
3. Advanced composites
4. SPF/DB titanium
5. RAM, canopy gold flashing
6. Cooled-plug 2-D nozzle
7. Fly-by-wire, relaxed static stability (U)

(U) Performance and sizing charts for the stealth concept are presented in Figures 104 and 105. The selected baseline airplane was chosen as having T/Wo - 0.33, Wo/S = 92 psf, and Wo = 302,396 lb.

(U) A summary of airplane characteristics and performance for the selected stealth concept is presented in Table 26. Mission summaries for the strategic (design) mission as well as theater and standoff missions are presented in Tables 27 through 29.

(S) TABLE 26. SELECTED STEALTH CONCEPT CHARACTERISTICS (U)

Takeoff gross weight, lb	302,396
Fuel weight, lb	164,882
Wing loading, psf	92
Thrust-to-weight	.33
Wing area, sq ft	3,287
Wing aspect ratio	2.0
Engine size	.831
Strategic mission range, n mi	5,250
Theater mission radius, n mi	[illegible]
Standoff mission patrol time, min	[illegible]
Takeoff distance, ft	5,987

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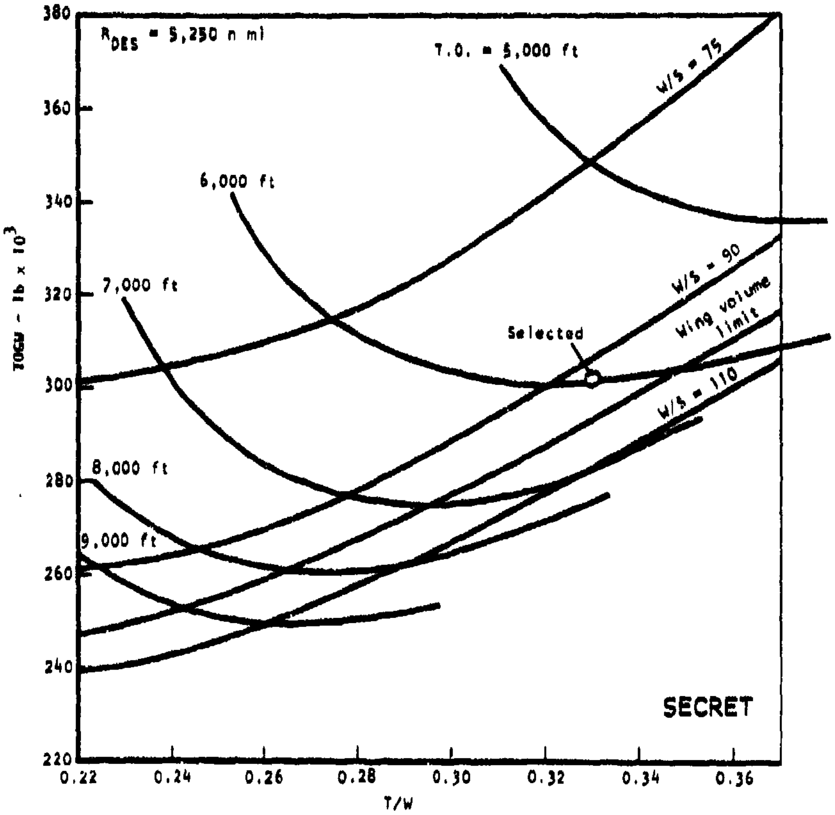
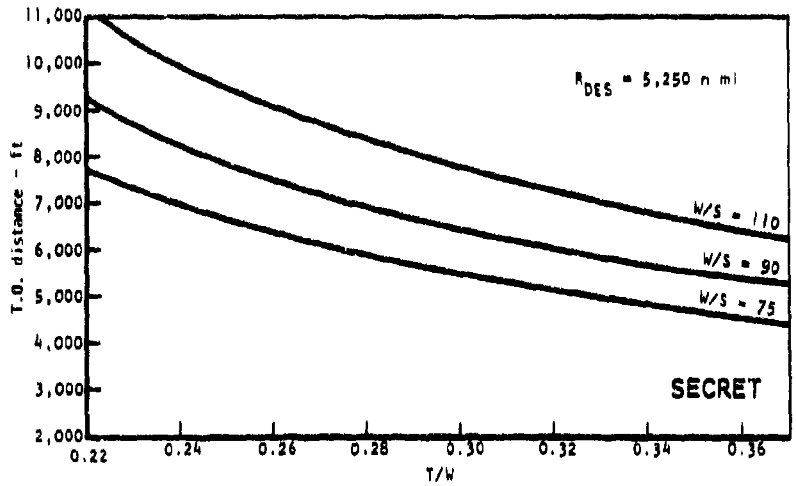


(S) Figure 104. Stealth Design Chart. (U)



(S) Figure 105. Stealth Takeoff Distance. (U)

(S) TABLE 27. STRATEGIC MISSION SUMMARY FOR SELECTED STEALTH CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	302,396						
Warmup & T.O.	299,394	0	0.705	3,002	5.00	0	0
Climb	294,949	22,201	.850	4,445	8.42	68.5	68.5
Cruise	216,992	20,336	.850	77,957	345.60	2,931.6	3,000.1
Penetrate	178,057	200	.720	38,936	126.24	1,001.4	4,001.5
Prop	128,057	200	.720	0	0	0	4,001.5
Withdraw	106,374	200	.500	21,682	136.34	751.0	4,752.5
Climb	103,636	47,138	.850	2,738	8.64	68.9	4,821.4
Cruise	98,590	48,220	.850	5,047	53.05	431.1	5,252.5
Loiter	95,755	0	.290	2,835	30.00	0	5,252.5
Reserve	87,514	0	0	8,241	0	0	5,252.5
Total fuel = 164,882 lb							

SECRET

(S) TABLE 28. THEATER MISSION SUMMARY FOR SELECTED STEALTH CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	302,396						
Warmup & T.O.	299,394	0	0.705	3,002	5.00	0	0
Climb	294,949	22,201	.850	4,445	8.42	68.5	68.5
Cruise	200,438	32,062	.850	94,511	435.30	3,678.8	3,747.3
Drop	150,438	37,124	.850	0	0	0	3,747.3
Cruise	98,588	48,303	.850	51,850	461.17	3,747.3	7,494.6
Loiter	95,753	0	.290	2,835	30.00	0	7,494.6
Reserve	87,514	0	0	8,239	0	0	7,494.6
Total fuel = 164,882 lb							

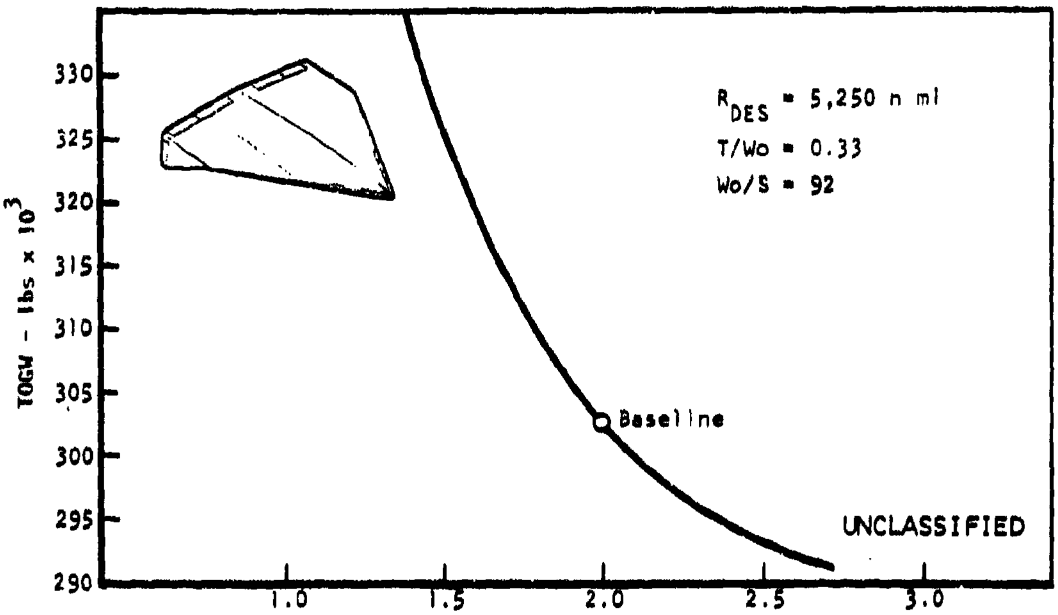
SECRET

(S) TABLE 29. STANDOFF MISSION SUMMARY FOR SELECTED STEALTH CONCEPT (U)

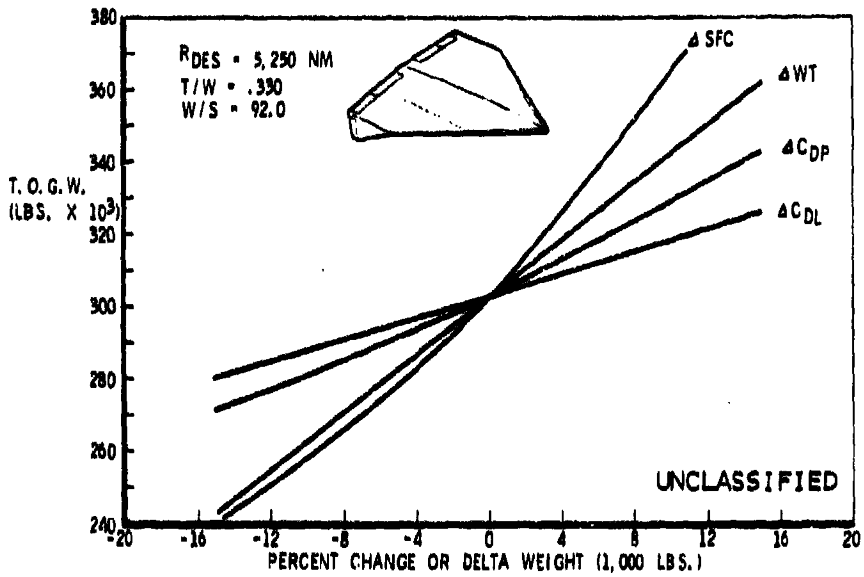
Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	302,396						
Warmup & T.O.	299,394	0	0.705	3,002	5.00	0	0
Climb	294,949	22,202	.850	4,445	8.42	68.5	68.5
Cruise	228,806	28,075	.850	66,143	285.65	2,431.5	2,500.0
Patrol	182,158	19,659	.582	46,648	280.92	0	2,500.0
Drop	132,158	19,659	.582	0	0	0	2,500.0
Climb	130,409	40,278	.850	1,748	5.61	45.2	2,545.2
Cruise	98,598	48,232	.850	31,811	302.11	2,454.8	5,000.0
Loiter	95,763	0	.290	2,835	30.00	0	5,000.0
Reserve	87,514	0	0	8,249	0	0	5,000.0
Total fuel = 164,882 lb							

SECRET

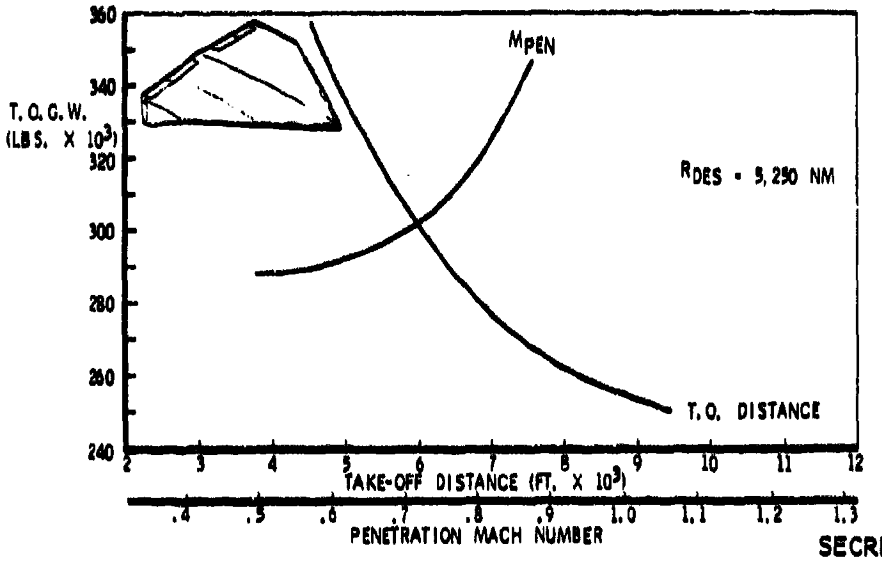
(U) Results of sensitivity trades for the stealth concept are presented in Figures 106 through 108. These trades were performed about the baseline airplane as selected in the preceding.



(U) Figure 106. Stealth aspect ratio trade. (U)



(U) Figure 107. Stealthy concept design trades. (U)



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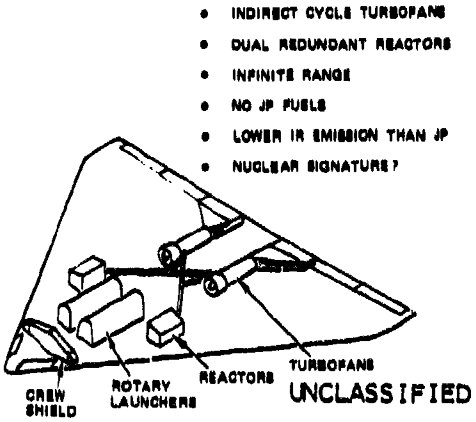
(S) Figure 108. Stealthy concept mission trades. (U)

Stealth Concept Design Trades

(U) The most interesting trade study on the stealth concept was a totally nuclear-powered configuration.

(U) This nuclear aircraft would have enough fuel for the reactor to perform extremely long endurance missions. Any combination of altitude and mach number within the thrust and structural limitations of the aircraft could be continued indefinitely. This would greatly increase the flexibility in the choice of missions and also allow the flight crew during a given mission to modify the mission profile, as required. Flight to and from the target area could follow a highly evasive course. High-speed missions at low altitude which normally are fuel-limited could be conducted for indefinite periods. The aircraft would fly at a constant gross weight which permits superior optimization of aircraft parameters.



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ENGINE CONCEPTS

	I	II	III	IV
SHIELDING	GROUND AUGMENTED		ALL FIXED	
DOSE RATE	1 REM/HR	.05 REM/HR	1 REM/HR	.05 REM/HR
REACTOR WT.	[illegible]	[illegible]	[illegible]	[illegible]
ENGINE WT.	19023	20024	[illegible]	[illegible]
INST. WT.	41864	44681	62426	[illegible]
THRUST: 2X	[illegible]	62700	[illegible]	108240
AC TOGW	361000	380000	[illegible]	[illegible]
PAYLOAD LB	50,000 LB			

(U) Figure 109. Nuclear powered stealthy. (U)

(U) Figure 109 summarizes the four nuclear engines considered and diagrams their installation. Note that the crew shield extends all around the crew via shielding in the aircraft skin, not shown.

(U) An in-depth discussion of the nuclear engines used is contained in Appendix E. Basically, all are indirect-cycle nuclear turbofans using high-pressure helium as the heat transfer medium. They differ according to allowable radiation exposure dose rates and the use of ground-augmented (or removable) shielding.

(U) As evident by the indicated takeoff weights, these concepts are within reason. Engine concept 2 provides a very reasonable takeoff weight at a very low radiation dose rate, and the required ground shield handling truck just replaces the unneeded fuel truck.

(U) However, it must be realized that the decision to build a nuclear-powered aircraft will be primarily political. The goal is to build a strategic system which will deter aggression, and that requires that the system be built. Therefore, this approach is not recommended unless it can be shown to be the only viable one, or overwhelmingly the most cost-effective solution.

	BASELINE	REMOVE SURFACE COATINGS	ACTIVE LAMINAR FLOW SUCTION	VCE
TOGW/LBS	302,396	324,800	277,430	293,000
WFUEL/LBS	164,882	183,190	131,780	159,900
WPAYLOAD	50,000	50,000	50,000	50,000
THRUST	2 x 49,895	2 x 53,592	2 X 45,776	2 X 48,400

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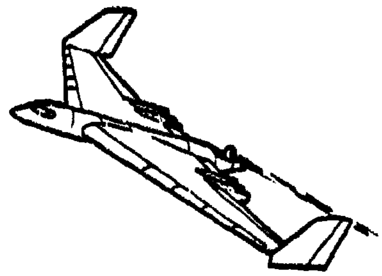
(U) Figure 110. Other design trades stealthy. (U)

Figure 110 shows the additional trade studies which were performed on the stealth baseline. As before, the surface coatings saved about 20,000 pounds. Active laminar flow suction, despite a 10,000-pound deadweight penalty, saved 25,000 pounds. The variable-cycle engine installation only saved 9,000 pounds.



(S) Figure 111. Defense laser baseline. (U)

LASER DEFENSE BASELINE

(S) Figure 111 summarizes the defensive laser baseline concept. The laser is a 1.5-megawatt EDL system capable of 60, 2-second bursts. The device, projector, tank farm, and electronics weight 16,000 pounds, which is based on projecting today's technology to the year 1995. The projector is in the very aft end of the aircraft to provide easy access and a good field of fire. The turret is on a pop-through mounting so that it can cover almost a 360-degree sphere.

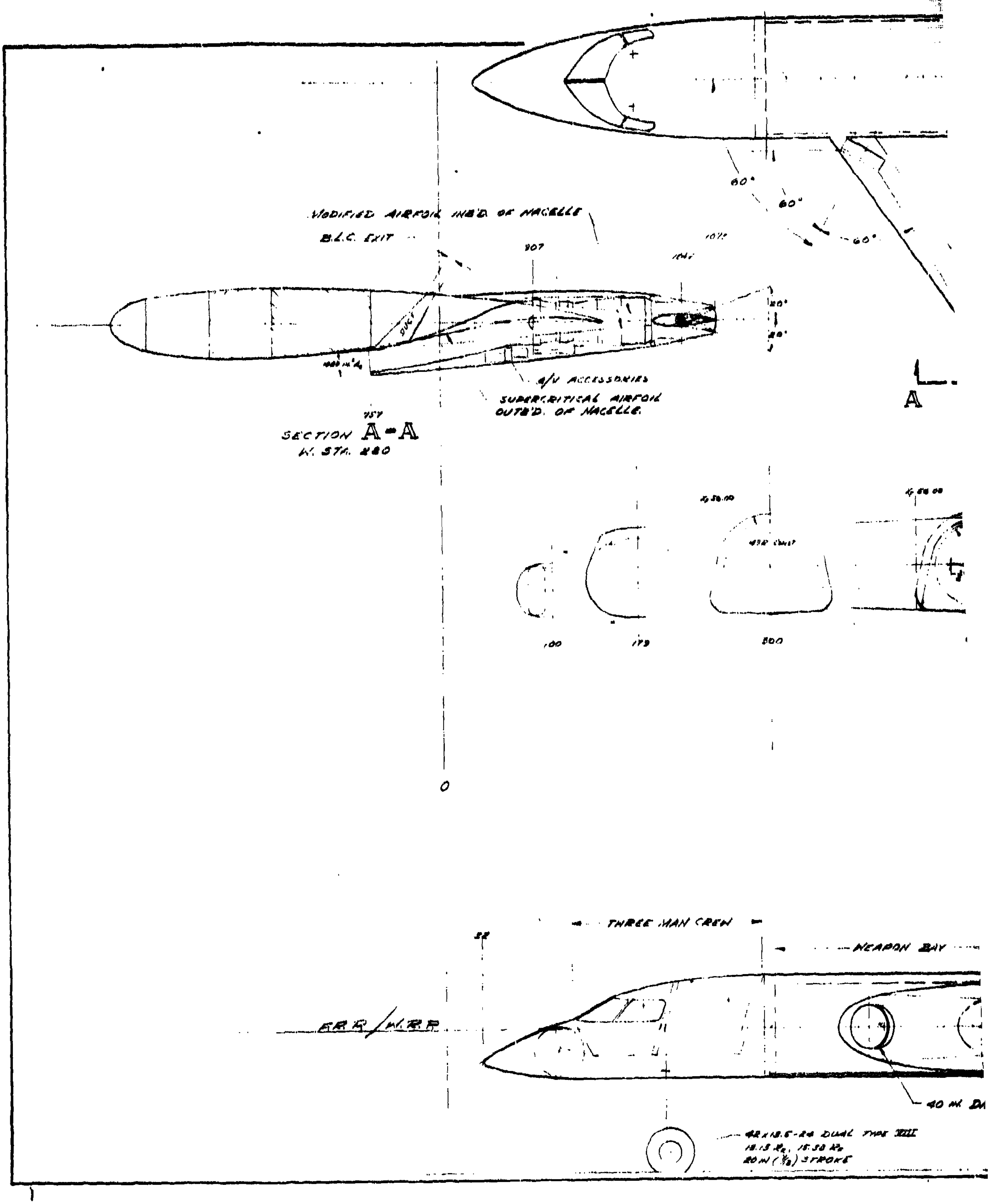
(U) The aircraft uses four small engines to reduce blockage of the field of fire and has 2-D nozzles for pitch trim and control. Winglets provide directional stability while reducing drag.

The following advanced technologies are employed:

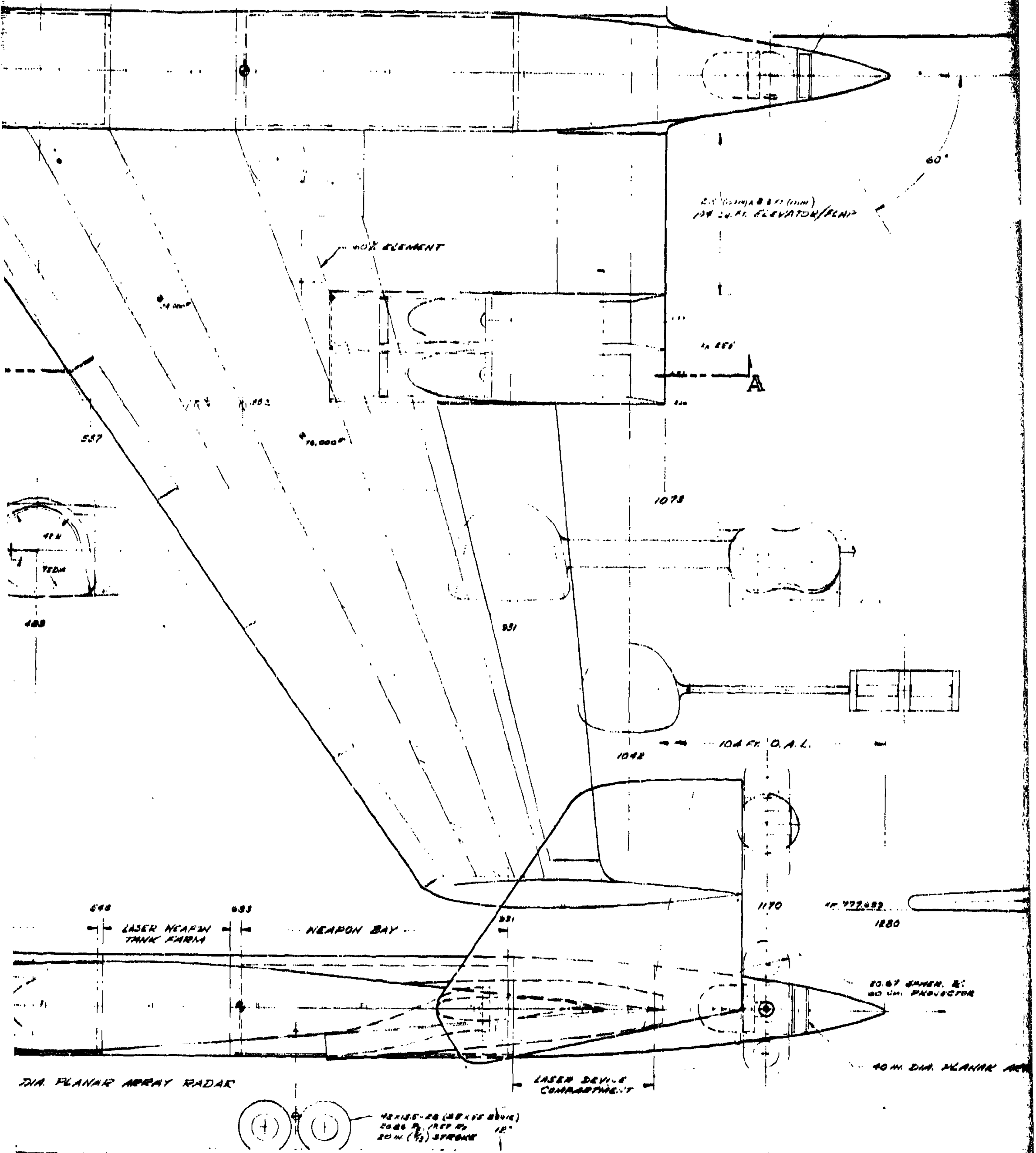
1. Supercritical wing
2. Aerodynamic surface coatings
3. Winglets
4. Composites
5. SPF/DB titanium
6. Relaxed static stability, fly-by-wire

UNCLASSIFIED

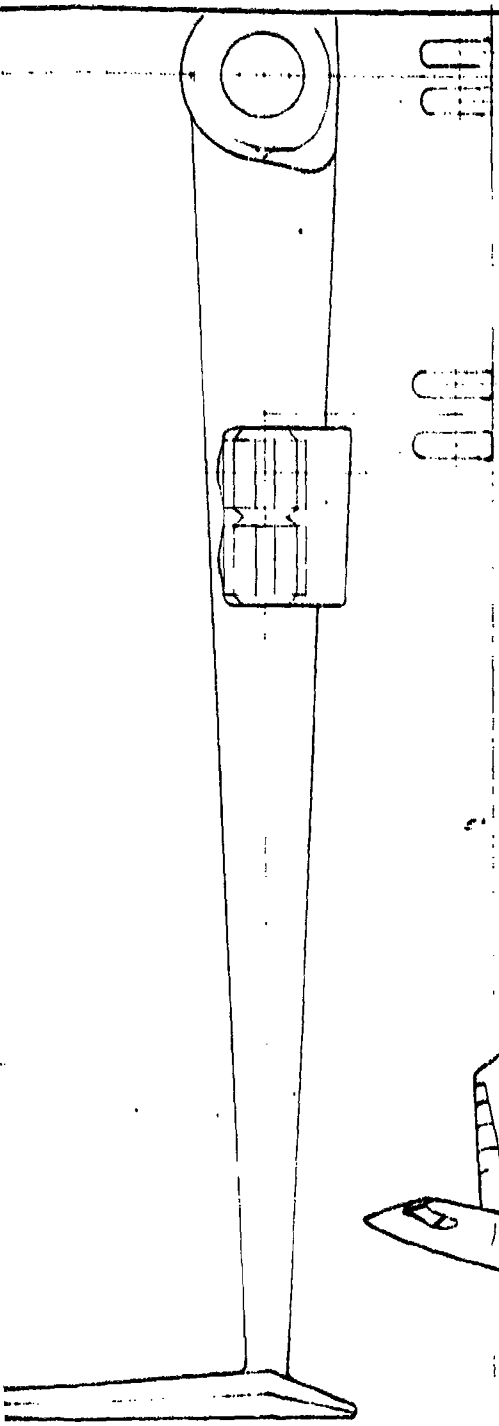
(U) Figure 112. Laser defense. (U)



MODIFIED AIRFOIL INB'D. OF NACELLE
B.L.C. EXIT
907
1047
60°
60°
60°
DUCT
20°
20°
A/V ACCESSORIES
SUPERCRITICAL AIRFOIL
OUTB'D. OF NACELLE
A
SECTION A-A
W. STA. 280
100
173
300
0
THREE MAN CREW
WEAPON BAY
F.R.P. / W.R.P.
40 IN. DIA
42x15.5-24 DUAL TYPE VIII
20 IN (1/2) STROKE



(U) Figure 113. Defensive laser co

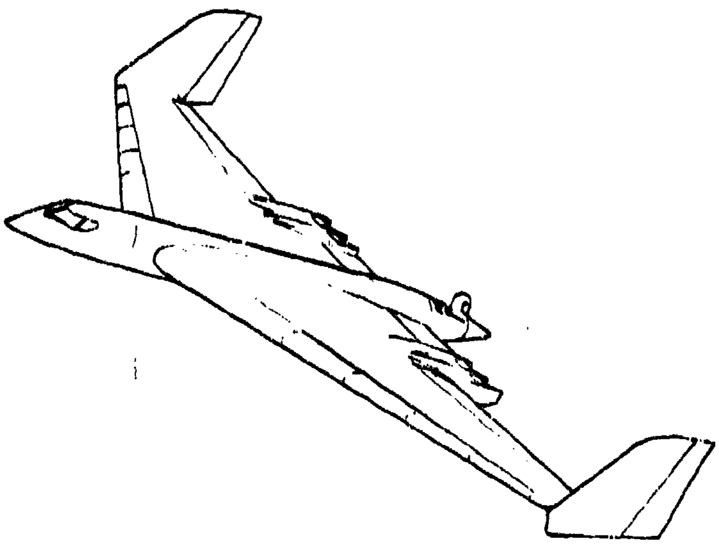


GEOMETRIC DATA			
ITEM	WING	VERTICAL	VENTRAL
S FT²	4200	320	55
AR	4.00	1.00	0.56
λ	0.25	0.50	0
Λ L.E.	35°	53.75°	50°
b IN.	1555.378	214.663	54.0
C_R	622.151	286.217	286
C_T	155.538	143.108	0
$\bar{c}$	435.506	222.618	189
XC̄	311.076	95.406	18
V	~	.0146 FT.	.0019 FT
ℓ_V	~	293	237
t/c	MX SUPERCR.	64A009	64A009

PROPULSION: 4 × 32000 LB. THRUST, 2.5 B.P.R., AUGMENTED ENGINES WITH 2-D NOZZLES. A_c = 1030 IN.² EA.

TARGET WEIGHTS:

420,000 LB. TOGW
220,000 LB. W_{EMPTY}
50,000 LB. PAYLOAD



PHASED ARRAY RADAR

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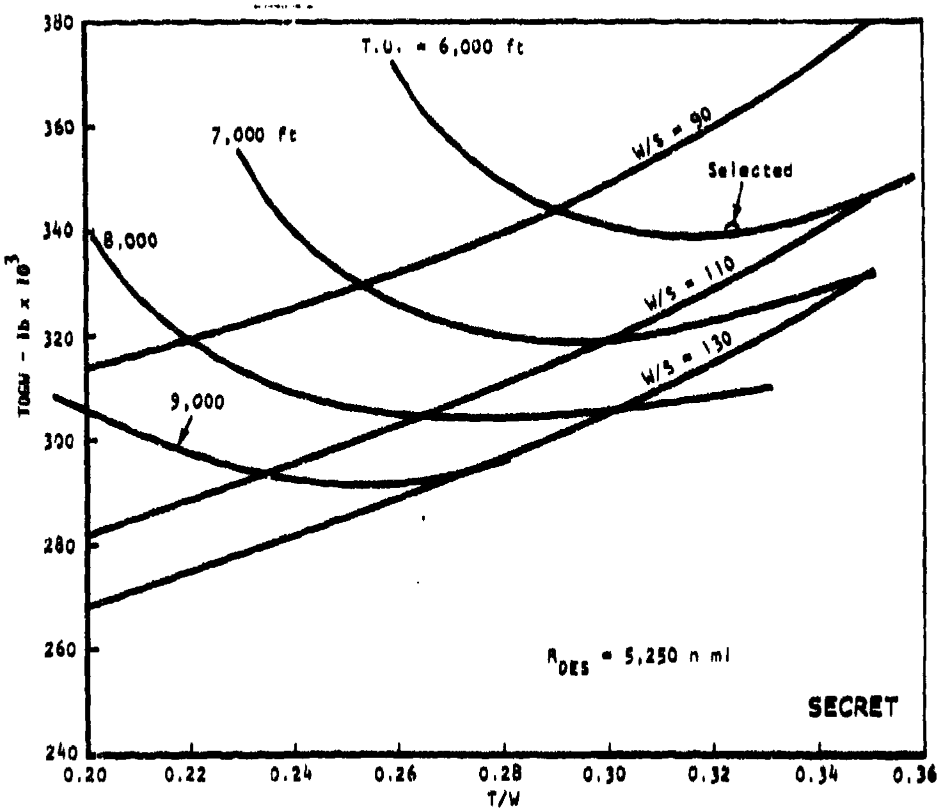
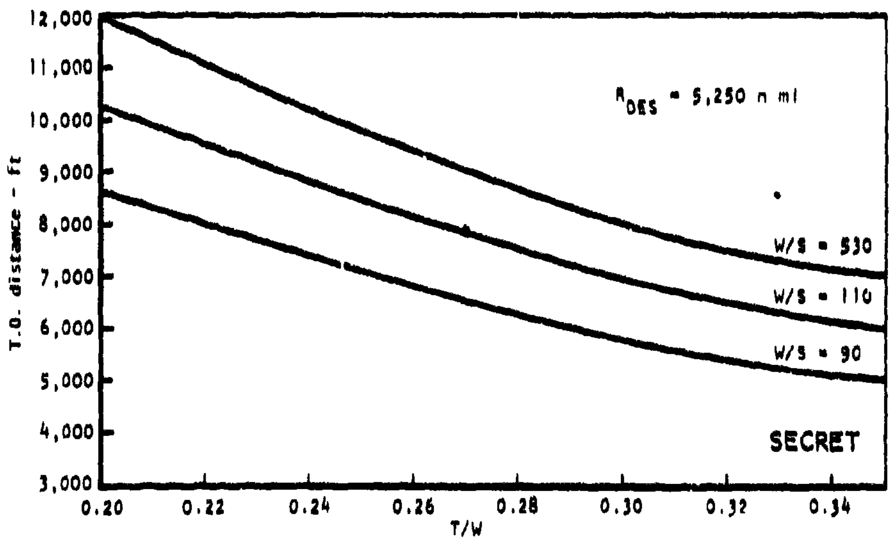
SCALE 1/50	DR. B. K. ROGERS DATE 1/20/78 MODEL 121	Rockwell International Corporation Los Angeles Aircraft Division INTERNATIONAL AIRPORT LOS ANGELES, CALIFORNIA	ADVANCED DESIGN
ISADS - DEFENSIVE LASER CONCEPT			D645-5

concept. (U)

(U) Performance and sizing charts for the laser defense concept are presented in Figures 114 and 115. The selected baseline airplane was chosen as having T/Wo = 0.324, Wo/S = 101.5 psf, and Wo = 340,808 lb.



(S) Figure 114. Laser defense design chart. (U)



(S) Figure 115. Laser defense takeoff distance. (U)

(U) A summary of airplane characteristics and performance for the selected laser defense concept is presented in Table 30. Mission summaries for the strategic (design) mission as well as theater and standoff missions are presented in Tables 31 through 33.

(S) TABLE 30. SELECTED LASER DEFENSE CONCEPT CHARACTERISTICS (U)

Takeoff gross weight, lb	340,808
Fuel weight, lb	169,718
Wing loading, psf	101.5
Thrust-to-weight	.324
Wing area, sq ft	3,358
Wing aspect ratio	4.0
Engine size	.460
Strategic mission range, n mi	5,250
Theater mission radius, n mi	3,927
Standoff mission patrol time, min	337
Takeoff distance, ft	5,959

SECRET

(U) Results of sensitivity trades for the laser defense concept are presented in Figures 116 through 128. These trades were performed about the baseline airplane as selected in the preceding.

(S) TABLE 31. STRATEGIC MISSION SUMMARY FOR SELECTED LASER DEFENSE CONCEPT (U)

Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	340,808						
Warmup & T.O.	337,486	0	0.672	3,321	5.00	0	0
Climb	331,613	28,982	.844	5,873	11.12	89.6	89.6
Cruise	259,299	34,310	.844	72,313	353.54	2,910.4	3,000.0
Penetrate	215,658	200	.720	43,642	126.14	1,000.5	4,000.5
Drop	165,658	200	.720	0	0	0	4,000.5
Withdraw	141,552	200	.800	24,106	136.23	750.4	4,750.9
Climb	137,797	47,800	.850	3,755	10.98	86.8	4,837.7
Cruise	132,616	48,630	.850	5,181	50.86	413.2	5,250.9
Loiter	129,568	0	.294	3,047	30.00	0	5,250.9
Reserve	121,090	0	0	8,478	0	0	5,250.9
Total fuel = 169,718 lb							

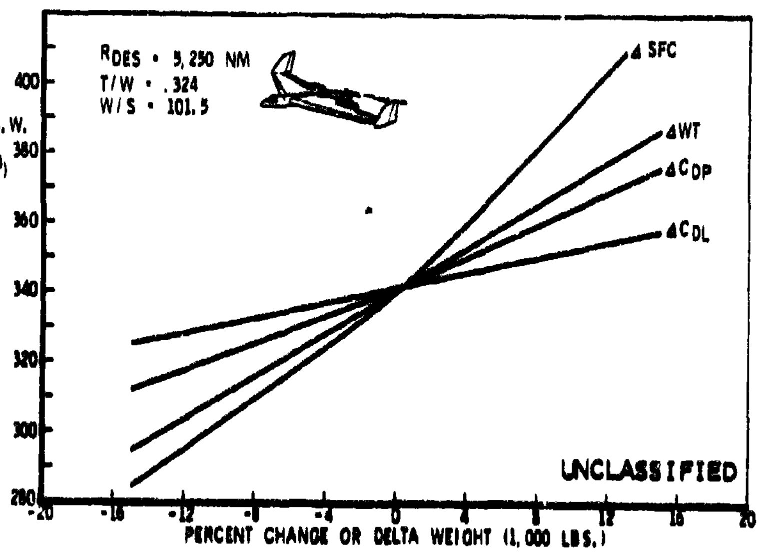
SECRET

(S) TABLE 32. THEATER MISSION SUMMARY FOR SELECTED LASER DEFENSE CONCEPT. (U)

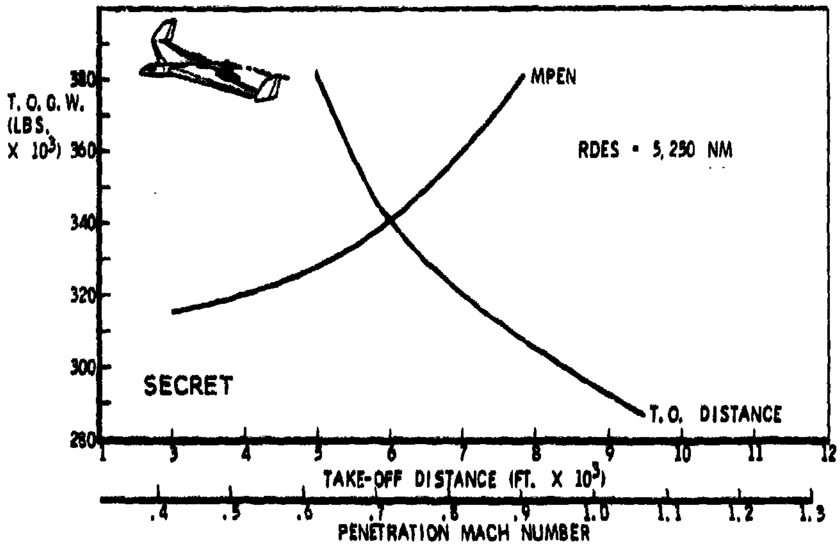
Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min).	Range (n min)	Total range (n min)
Initial weight	340,808						
Warmup & T.O.	337,486	0	0.672	3,321	5.00	0	0
Climb	331,613	28,952	.844	5,873	11.12	89.6	89.6
Cruise	239,558	35,963	.844	92,055	467.88	3,837.5	3,927.1
Drop	189,558	35,963	.844	0	0	0	3,927.1
Cruise	132,616	48,642	.850	56,942	484.98	3,927.1	7,854.2
Loiter	129,569	0	.294	3,047	30.00	0	7,854.2
Reserve	121,090	0	0	8,479	0	0	7,854.2
Total fuel = 169,718 lb							SECRET

(S) TABLE 33. STANDOFF MISSION SUMMARY FOR SELECTED LASER DEFENSE CONCEPT (U)

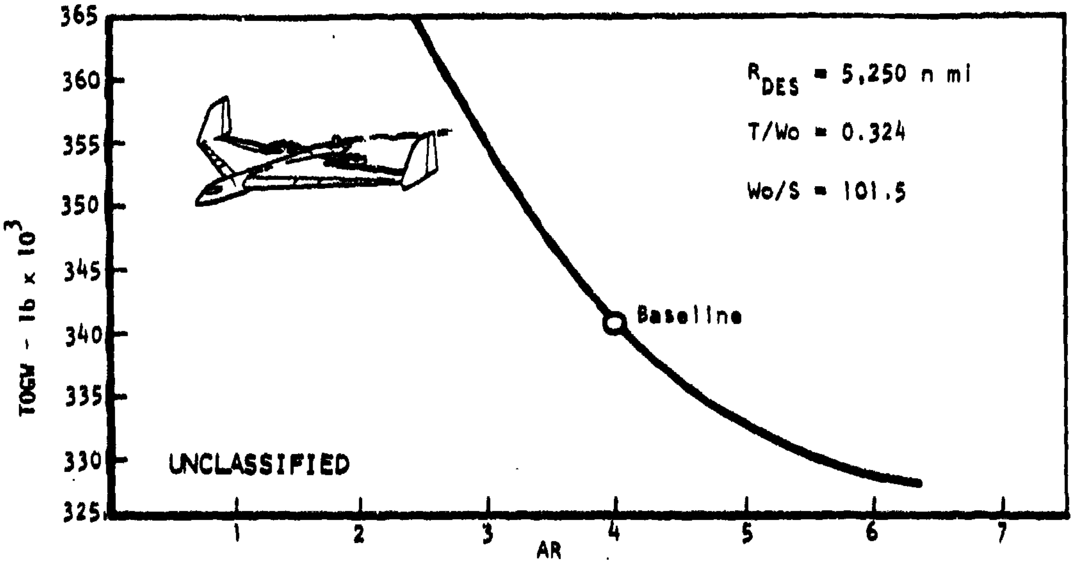
Leg description	Weight (lb)	Altitude (ft)	Mach No.	Fuel used (lb)	Time (min)	Range (n min)	Total range (n min)
Initial weight	340,808						
Warmup & T.O.	337,486	0	0.672	3,321	5.00	0	0
Climb	331,613	28,952	.844	5,873	11.12	89.6	89.6
Cruise	270,573	33,376	.844	61,040	292.20	2,410.4	2,500.0
Patrol	218,482	19,980	.560	52,090	337.54	0	2,500.0
Drop	168,482	19,980	.560	0	0	0	2,500.0
Climb	165,869	43,714	.846	2,614	8.50	67.7	2,567.7
Cruise	132,628	48,631	.850	33,240	300.04	2,432.3	5,000.0
Loiter	129,581	0	.294	3,047	30.00	0	5,000.0
Reserve	121,090	0	0	8,491	0	0	5,000.0
Total fuel = 169,718 lb							SECRET



(U) Figure 116. Laser defense concept design trades. (U)



(S) Figure 117. Laser defense concept mission trades. (U)



(U) Figure 118. Laser defense aspect ratio trade. (U)

Laser Defense Concept Design Trades

(U) No specific trade studies were conducted on the laser defense concept. Note that allowances for laser systems weighing other than 16,000 pounds can be made by reading the gross weight as a function of change in deadweight in Figure 116.

(U) Also note in the same figure that removing the laser entirely (delta weight = -16,000 pounds) produces a takeoff weight of about 280,000 pounds. This is less than the weight of the minimum weight concept and is due to the use of four rather than two engines. This reduces the total excess thrust carried to allow one engine-out performance, which, in turn, improves the total cruise fuel consumption. However, this increases cost and complexity. For this reason, an engine number trade study is recommended for follow-on work.

Section IV

COST STUDIES

(U) Life cycle costing (LCC), which encompasses development, production, support investment, and operations and support costs, has become an integral part of system programs at all levels of development. Inclusion of LCC in the ISADS program at this conceptual design level has contributed significantly to the value of the study. In addition to providing a common denominator for comparing configurations and supporting trades, LCC's were used as a design parameter for identifying cost drivers and as a first-order design-to-cost goal for the next-generation strategic penetrating bomber.

(U) LCC estimates were prepared for each final design configuration in accordance with a set of costing guidelines, as follows:

1. All costs are in constant FY 1977 dollars without allowance for future escalation or inflation.

2. There are four flight test airplanes, with any other airplanes used in flight test being refurbished and becoming production articles. There are 200 production airplanes.

3. LCC's are calculated for 15 years. There are 15 unit equipment (UE) per squadron and 400 flying hours per UE per year. Only peacetime costs are considered.

4. Fuel costs are $0.44 per gallon, and the sensitivity of LCC to 50- and 100-percent increases in fuel cost is shown.

(U) The LCC of the configuration was developed using three costing models that address research, development, test, and evaluation (RDT&E); production (PCM); and operation and support (FCOST). The RDT&E model uses cost-estimating relationships (CER) for engineering, fabrication, and test to calculate all of the costs for this portion of the total LCC. The PCM is a statistical/parametric model used to develop production costs for advanced aircraft systems where only general weight, geometric characteristics, material, and fabrications process data are available. Both the RDT&E and the PCM incorporate equations similar to those developed by Rand to estimate respective propulsion costs. The FCOST model uses CER's based on similar operational aircraft to calculate the operation and support cost of the aircraft force over a specified period of years. It also adds all costs for the total LCC summary when so directed. The costing models were validated using the B-1 as a source of input, including the 240 aircraft buy size. The output values forthe B-1 are given in Table 34 together with the June 1977 System Acquisition Report (SAR) values for comparison.

(U) Certain B-1 program cost data were used directly or as a basis for developing portions of the ISAD design LCC estimates. Specifically, in the RDT&E those costs allocated to the B-1 for advanced development tasks, program development tasks, and other government costs are not generated in the costing model. These costs, assumed equal to those for the B-1, have been added to RDT&E for all configurations under the heading of "other."

(U) The PCM accounts for recurring and nonrecurring costs as they apply to the airframe and its associated systems, with the exception of propulsion and avionics. Therefore, the B-1 costs for nonrecurring and for sustaining engineering on these two systems have been included in the unit flyaway cost category, "other," for each of the five configurations.

(U) The cost of the laser that is carried on the laser defense configuration was not included in the cost of that aircraft. This decision was based on the uncertainty surrounding laser design, the technology improvements that would be difficult to include in the RDT&E costs, and the stated objective of the study which is directed at the technologies of aircraft aerodynamics and innovative design.

(U) Calculations for the 15-year operation and support (O&S) costs generally were based on B-1 values, as follows. A ratio of the unit flyaway cost of each configuration to the B-1 was used to develop the annual values for depot maintenance (both cost per UE and cost per flying hour), the cost of common operational support equipment (OSE), and the cost of replenishment spares. The base material cost of the B-1 was used as a constant for all configurations. Maintenance man-hours required per flight hour for the B-1 were adjusted for each configuration according to recognizable differences in the quantities or types of systems. These were used by the model to calculate manning and related requirements. The avionics RDT&E and production costs used for the five configurations were based on the avionics costs of the B-1. The assumption was made that improved capabilities would be required for the ISADS avionics that would require a comparable expenditure. Adjustments were made for the avionics costs of two configurations. The high penetration speed of the "Minimum Penetration Time" configuration was assumed sufficient to eliminate the need for ECM in the rear quadrant, and the cost was changed accordingly. The "Laser Defense" configuration avionics costs were increased in proportion to the additional weight required for the laser fire control avionics.

(U) A summary of the more significant of the costs generated by these models is given in Table 34. The empty weight values of the five are also given at the bottom of each column, together with a ratio of the configuration empty weight to the B-1 empty weight. These added data were considered important in answering the obvious question, "why are these unit flyaway costs so low compared with the cost of the B-1?" which would be approximately $60.5 m for an equivalent 200-unit buy size. The answer is that weight is the prime cost driver, and the ISADS designs are generally lower weight than the B-1. This fact is reflected in the final line on Table 34 where a flyaway cost ratio of the ISADS configurations to the 200-buy B-1 ($60.5 m) indicates the same general relationship as the weight ratios. The complete set of costs for the five configurations that were generated by the cost models have been included as Appendix F to this report.(U)

(U) The impact of the simplistic aspects of the low-cost design (viz, constant chord and rib shape for the wing and canard and the constant fuselage frame section for over 50 percent of the length) was reflected in the acquisition costs. Data were extracted from the PCM output and used to develop a breakdown of the various costs of the vehicle, as shown in Figure 119. The left column is according to the WBS format. The middle column aggregates costs differently so that costs that could be affected by the simplistic design could be assessed. The right column is a breakdown of the manufacturing labor costs, normalized, as they apply to the various parts of the aircraft. As shown, the hours attributable to the fuselage are the largest for structure. Consider that while the shape of the fuselage frames at different stations might be the same, the number, and therefore the amount, of handling and manufacturing tasks remain almost the same as for a nonuniform fuselage. Even if a savings of 10 percent is realized in the fuselage manufacturing labor costs, the change to the unit cost will be less than 1 percent. The point here is that simplifying the design will help lower the cost, but there are other considerations beyond the scope of this study that may be more significant. (U)

(U) TABLE 34. COST METHOD VALIDATION AND ISADS CONFIGURATION COST BREAKDOWN (1977 $ M) (U)

	B-1 (240 A/C)	ISADS (200 A/C Buy)				
		Low cost	Low weight	Min pen. time	Stealth	Laser def
Life cycle	28,438	16,753	15,246	24,800	15,804	18,767
RDT&E	4,130 (4,086)	3,153	2,865	4,682	2,907	3,147
Airframe	1,055	1,270	1,005	2,668	1,027	1,197
Propulsion	548	346	235	464	252	211
Avionics	202	202	202	194	202	404
Other	1,335	1,335	1,335	1,336	1,335	1,335
Acquisition	15,903 (15,550)	8,227	7,292	12,505	7,607	9,630
Production	15,400	7,848	6,933	12,067	7,241	9,195
Flyaway	12,085	6,887	6,084	10,589	6,354	8,068
Spares, AGE, etc.	2,515	961	849	1,478	887	1,126
Other invest.	494	378	358	437	366	435
O&S (15 yr)	8,315 at 313 M/YR	5,374	5,089	7,313	5,290	5,990
Unit flyaway	54.1 (57.7)	34.4	30.4	52.9	31.8	40.3
Airframe	37.0	19.7	16.3	34.9	15.9	21.5
Propulsion	7.0	4.8	4.3	10.6	6.0	6.4
Avionics	6.9	6.9	6.9	4.5	6.9	9.8
Other	3.2	3.0	3.0	3.0	3.0	3.0
Empty wt (lb)	178,374	98,211	83,805	167,098	79,642	109,108
ISADS/B-1 emp wt ratio	-	0.55	0.47	0.94	0.45	0.61
ISADS/B-1 cost ratio	-	0.57	0.50	0.87	0.53	1.07

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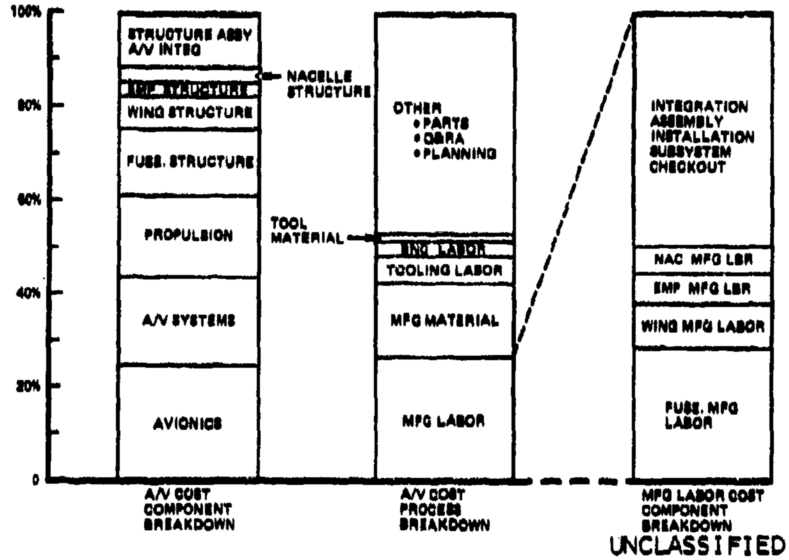
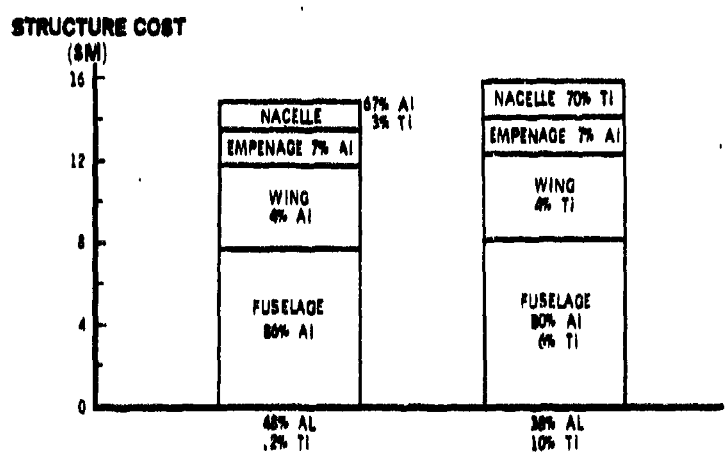


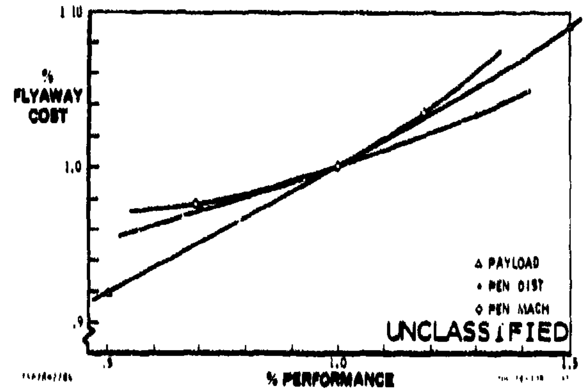
(U) Figure 119. Air vehicle cost breakdown (low-cost configuration) (U)

(U) Another examination of the low-cost configuration considered the impact of using aluminum instead of titanium in all but the hot section of the nacelles. Figure 120 depicts the change in the structural cost brought about by this change in material. It amounts to about 4 percent. Equal weights of both materials were assumed.

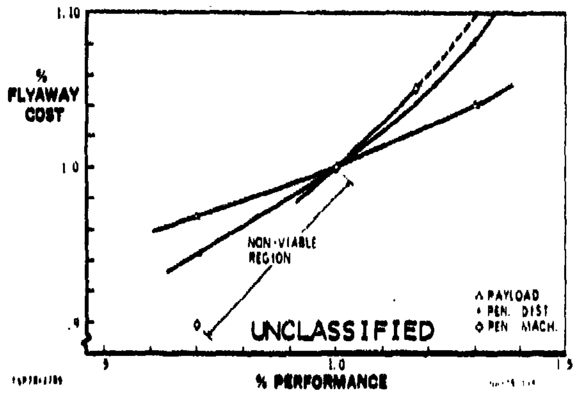


(U) Figure 120. Material trade (low-cost configuration). (U)

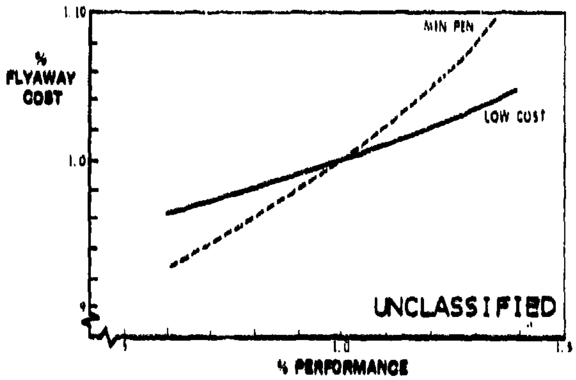
(U) A sensitivity analysis was conducted to determine how changes to the performance requirements would affect aircraft weight and, therefore, cost. The low-cost and minimum-penetration-time configurations were examined, and the results were compared in terms of relative performance versus relative cost. The advanced design sizing model was used to develop changes to the weight of the aircraft as a function of changes to the payload, penetration distance, and penetration mach number. The results of this analysis are depicted on Figures 121 and 122 for the two configurations. It should be recognized that the curves reflect the trends rather than absolute relationships because the configuration designs were not optimized for the differences; rather the aircraft were grown or shrunk according to the performance parameters. Figure 123 compares the cost-performance trend of the two configurations for the penetration distance variable, where the higher speed aircraft is more seriously affected. (U)



(U) Figure 121. Cost versus performance (low-cost variation). (U)



(U) Figure 122. Cost versus performance (minimum penetration variation). (U)

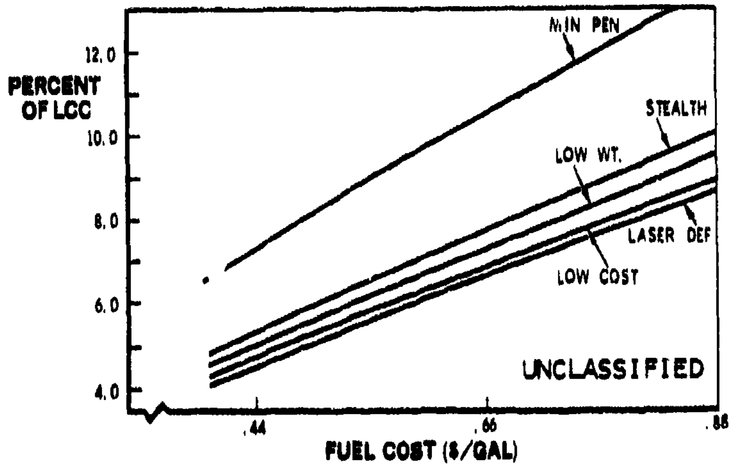


(U) Figure 123. Air vehicle performance versus cost comparison (penetration distance variable). (U)

(U) Consideration of these trends of cost-performance relationships points out that the operational requirements that are imposed on a design have great impacts on the final cost of the aircraft. Competent contractors exercise control where feasible, but the percentage margin they have to work with is not very large. This is illustrated by the relatively small span of unit flyaway costs summarized in Table 34.

FUEL COST IMPACT

(U) One of the requirements of the study was to determine the impact of fuel cost on LCC, assuming a fuel cost of $0.44 per gallon as well as values 50 and 100 percent higher. The results of this analysis are shown in Figure 124. When the fuel costs for 15 years of operations are compared with total O&S costs, the percentages range from 14.2 percent at the low end of the laser defense line to 39.2 percent at the upper limit of the minimum penetration line. Such a large cost factor must be carefully considered in future aircraft studies.



(U) Figure 124. Fuel cost impact on LCC. (U)

Section V

PROGRAM PLANNING

INTRODUCTION AND SUMMARY

(U) The program plan portion of the ISADS final report is divided into three sections. The first section, "Advance Technology Schedules," includes background material relating to all advance technology subjects considered in the ISADS program planning task. It also includes "lead-in" program schedules for selected advance technologies.

(U) The second section, "Master Program Schedules - Technology Advancement/Configuration Definition," contains summary schedules which depict the milestones, activities, and time required for each of the five ISADS design concepts, from the present time to RDT&E go-ahead.

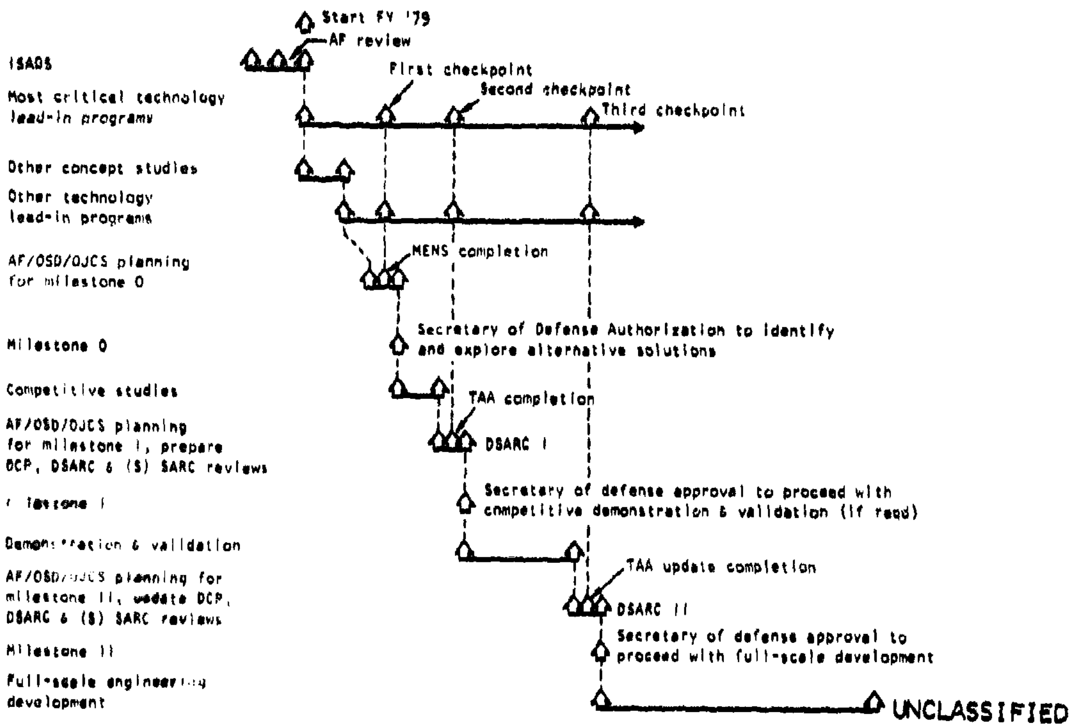
(U) The third section, "Master Program Schedules - RDT&E/Production," includes detail schedules which highlight the milestones, major activities, and time required for each of the five concepts, from RDT&E go ahead through delivery of the final production aircraft.

(U) Figure 125 summarizes the considerations followed by Rockwell in establishing the ISADS program plan.

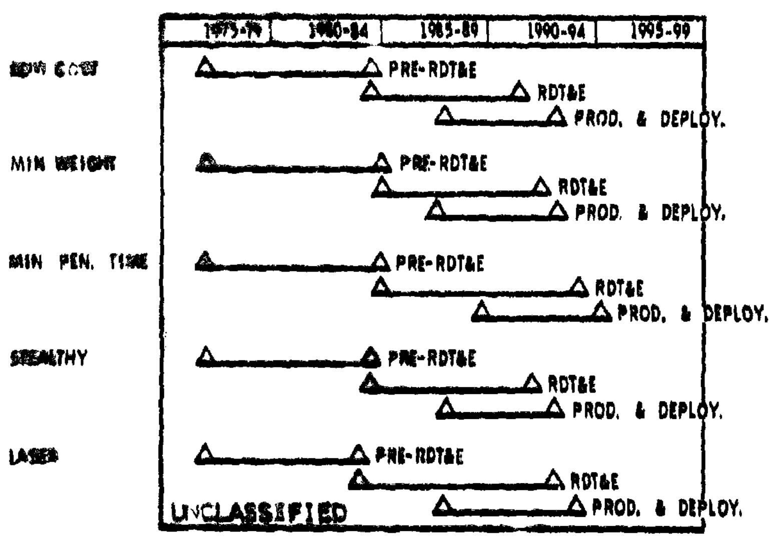
(U) Figure 126 summarizes the total program schedules for the five baselines.

ADVANCE TECHNOLOGY SCHEDULES

(U) The 50 advance technology subjects considered in the ISADS program planning task are listed in Table 35. Category A items are recommended as separately funded advance technology lead-in programs which should be substantially completed prior to Milestone II. Some category A items are follow-on efforts to ongoing research programs. Lead-in programs are not required for Category B items. In these cases, it is estimated that sufficient time will be available to explore the required technology concurrent with applicable full-scale engineering development programs.



(U) Figure 125. Flow diagram - ISADS technical advance schedule relationship to DOD directives 5000.1/2 milestones. (U)



(U) Figure 126. ISADS Master Program Schedule Summaries. (U)

(U) Table 35.
ISADS TECHNOLOGIES (U)

Number	Technology	Category
	Propulsion	
101	Current engine	B
102	Variable-cycle engine	A
103	Multimode integrated propulsion system	A
104	Nuclear	A
105	Advanced conventional engine	A
106	Turbo prop	B
107	Ratio	B
	Fuels	
108	LH_2	A
109	Slush H_2	B
110	JP (Adv)	B
111	Shelldyne	B
	Nozzles	
112	Nonaxial nozzles	B
	Controls	
201	Integrated propulsion controls	B
202	2-D vectorable	A
203	Structural mode controls	B
204	Relaxed static stability	B
205	Maneuver load control	B
206	Active flutter suppression	B
207	Gust alleviation	B
208	Fly by wire	B
	Aerodynamics	
301	Boundary layer control	B
302	Surface coatings	A
303	Advanced supercritical wing	B
304	Nonplanar wing	B
305	Advanced variable camber	B
306	Coplanar wing	A
307	Blended wing-body	B
308	Forward wing sweep	A
309	Skewed wing	A
310	Variable sweep	B
311	Ground effect	A
	Structures/materials	
401-1	Advanced composites	A
401-2	Advanced composites	A
401-3	Advanced composites	A
402-1	Metallic material	A
402-2	Metallic material	A
402-3	Metallic material	A
403	Metal matrix	A
404	Aeroelastic tailoring	A
405	Near-net diffusion bonding	B
406	Superplastic forming/diffusion bonding	A
407	Periodic slot array radome	A
	Low Observables	
501	Planar retreating surfaces	B
502	Engine face obscuration devices	A
503	Cooled plug nozzles	A
504	Paints and coatings	B
505	Fill-in lights	B
506	Sealing and bonding	B
507	Metallic flashing on cockpit glass	B
508	RAM	A

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(U) The applicability of Category A items to the five ISADS conceptual designs is listed in Table 36.

(U) TABLE 36. TECHNOLOGY APPLICATIONS (U)

Number	Low cost (D645-1)	Min pen time (D645-3)	Stealth (D645-4)	Def laser (D645-5)	Min weight (D645-6)	Not applicable
102		X				
103						X
104						X
105	X			X	X	
108						X
202		X	X	X		
302	X				X	
306						X
308	X					
309		X				
311						X
401-1			X	X		
401-2			X	X		
401-3			X	X		
402-1						X
402-2						X
402-3						X
403						X
404						X
406	X	X	X	X	X	
407						X
502						X
503						X
504						X
508			X			

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(U) The items listed as "not applicable" were examined for broad potential application to ISADS, but they do not specifically apply to any of the five conceptual designs presented by Rockwell in this report. Appendix G details the schedules which were developed for Category A items. Each schedule contains an entry designated "input to TAA" (technology assessment annex). The TAA is defined in DOD Directive 5000.1 as "a one page description of technological risks remaining in a system program and the plans to address these risks." The TAA is a key element in the decisionmaking process at Milestones I and II. In some cases (i.e. item 104, Nuclear Engines), the "Input to TAA" milestone is followed by Milestone I and a demonstration and validation program. In other cases (i.e. item 102, Advanced Conventional Engine), the option of proceeding either to Milestone I or directly to Milestone II is left open. In these cases, the decision will rest upon the degree of program progress up to that point in time.

(U) Rockwell has assumed that the requirement for a demonstration and validation phase would be bypassed for the purpose for establishing schedule requirements leading up to RDT&E. The rational for this assumption is documented in the following paragraphs.

MASTER PROGRAM SCHEDULES-TECHNOLOGY ADVANCEMENT/CONFIGURATION DEFINITION

(U) Separate schedules (appendix I) have been established to depict the milestones, activities, and time required for each of the five ISADS design concepts, from the present time to RDT&E go-ahead. The time period between the end of the existing study (30 June 1978) and the availability of funds (1 October 1979) to proceed with advanced technology programs having future applicability to ISADS has been set aside for Air Force actions. These actions include Air Force review of ISADS final reports, solicitation of industry proposals for selected advanced technology programs and ISADS follow-on studies, contractor proposal preparation, and contract negotiations. Those advanced technology lead-in program schedules which have application to specific ISADS design concepts have been summarized for inclusion into the master program schedules. The technology program which requires the longest time for documentation of successful achievements into the TAA establishes the critical path to RDT&E go-ahead. This path is represented by the dotted line on each schedule.

(U) The ongoing programs related to SPF/DB are documentated in Metallic Structures Roadmap, published by the Air Force Materials Laboratory (AFML). These programs include current contracts applicable to build up low-cost advanced titanium structure (BLATS), and limits of process. Other SF/DB programs which are in the advanced planning stages include a NASA-sponsored subsonic cruise aircraft research (SCAR) structural development program and Air Force studies related to skin design, hardware validation for ATF, innovative low-cost tooling, and size scaleup. All of the aforementioned programs will complement and support the Rockwell identified SF/DB program for titanium reduction to practice and the establishment of a design manual. NASA, FDL, and APL are sponsoring industry and in-house efforts related to 2-D nozzles. NASA- and FDL-sponsored current and expected programs are devoted to vectored thrust and 2-D wedge research, cooling studies, and wind tunnel testing. APL and FDL have ongoing programs covering aircraft propulsion system integration (APSI) wind tunnel tests and installed turbine engine survivability criteria (ITESC) static tests. In addition, APL is planning programs for APSI full-scale demonstration, IR/RCS reduction models, and full-scale static tests. All of these programs will dovetail into the Rockwell identified 2-D vectorable nozzle program.

(U) Other Government and industry programs are either planned or currently underway which will support Rockwell identified programs related to composites, skewed wing, and forward swept wing advanced technology advancement requirements.

(U) Activities which are scheduled to proceed in parallel with the Rockwell-recommended advanced technology lead-in programs are ISADS follow-on studies, AF/OSD/OJCS planning for Milestone 0, and competitive studies. After inputs to the TAA are completed, the necessary activities leading up to RDT&E go-ahead are scheduled. These activities include AF/OSD/OJCS planning for Milestone II and solicitation of proposals for full-scale engineering development.

(U) For the purpose of schedule consistency with the B-1 program and in the belief that DOD would prefer, for a new strategic bomber program, to move directly from the competitive studies stage to full-scale engineering development, the competitive demonstration and validation phase has been bypassed. The rational for this assumption is the belief that sufficient funding to proceed in parallel with two programs of this magnitude would not be available. It is possible that separate competitive demonstration and validation of certain advanced technologies, such as those planned for advanced engines, may prove to be necessary at a later date. This would also have the effect of extending the total time required to achieve total system IOC.

Scheduled RDT&E go-ahead dates are as follows:

Design Concept	RDT&E Go-Ahead
Low cost (D645-1)	1 May 1984
Minimum penetration time (D645-3)	1 September 1984
Stealth (D645-4)	1 September 1984
Defensive laser (D645-5)	1 September 1984
Minimum weight (D645-6)	1 September 1984

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(U) An alternate approach would be to proceed with an aircraft demonstration and validation phase, and to use this experience to minimize the RDT&E flight testing. This approach, which may be politically more acceptable, was not specifically addressed in this study but will be investigated in follow-on efforts.

MASTER PROGRAM SCHEDULES - RDT&E/PRODUCTION

(U) Appendix J presents the ISADS master schedules for the period after RDT&E go-ahead. In general, the B-1 master program schedule (Appendix H) was used as a model for deriving the ISADS schedules. This is a composite of the B-1 RDT&E program as it is presently constituted plus the production program, as planned prior to cancellation in June 1977.

(U) Rockwell has assumed that the requirement for a demonstration and validation phase would be bypassed for the purpose for establishing schedule requirements leading up to RDT&E. The rational for this assumption is documented in the following paragraphs.

MASTER PROGRAM SCHEDULES-TECHNOLOGY ADVANCEMENT/CONFIGURATION DEFINITION

(U) Separate schedules (appendix I) have been established to depict the milestones, activities, and time required for each of the five ISADS design concepts, from the present time to RDT&E go-ahead. The time period between the end of the existing study (30 June 1978) and the availability of funds (1 October 1979) to proceed with advanced technology programs having future applicability to ISADS has been set aside for Air Force actions. These actions include Air Force review of ISADS final reports, solicitation of industry proposals for selected advanced technology programs and ISADS follow-on studies, contractor proposal preparation, and contract negotiations. Those advanced technology lead-in program schedules which have application to spefic ISADS design concepts have been summarized for inclusion into the master program schedules. The technology program which requires the longest time for documentation of successful achievements into the TAA establishes the critical path to RDT&E go-ahead. This path is represented by the dotted line on each schedule.

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(U) On the B-1 program, aircraft No. 1 and 2 (A/C-1 and -2) were of essentially the same design, with relatively minor design changes occurring on A/C-2. Significant design changes occurred on A/C-3. These were followed by additional major design changes on A/C-4.

(U) For ISADS scheduling purposes, in each of the five cases, A/C-1 and A/C-2 are considered to be of the same basic design. Time for major design changes is included in schedules for A/C-3. All remaining flight test aircraft are considered to be of the same basic design as A/C-3. A/C-3 constituted a significant design change over the first two aircraft in order to accommodate installation of the offensive avionic system and associated cooling equipment. Redesign of the B-1 to install the defensive avionic system was delayed until a later point in time (A/C-4). These changepoints were selected because of funding constraints and technical reasons which existed at that time. Whether similar circumstances would exist during the ISAD RDT&E program(s) cannot be precisely predicted at this time. For ISADS scheduling purposes, Rockwell has established a ground rule that a redesign of A/C-3 would be programmed to accommodate installation of both the offensive and defensive avionic systems.

(U) B-1 A/C-4 constituted a major design change over the first three aircraft. The most significant change, other than the installation of the defensive avionic system, involved the redesign of the forward fuselage to delete the crew escape capsule and incorporate ejection seats. Other significant changes included cost-reduction redesigns of the nacelles, aft fuselage, aft intermediate fuselage, wing, and wing carry-through structure. For ISADS scheduling purposes, Rockwell has assumed that the circumstances which required these changes to the B-1 would not be repeated on ISADS. Therefore, no separate redesign of A/C-4 has been indicated in the five ISADS schedules.

(U) The B-1 flight test program, as indicated in Appendix H, ends on 13 March 1979 as presently contracted. The planned and anticipated programs for flight test of A/C-4 are also indicated. At the time of production cancellation (June 1977), initial plans and schedules were being prepared for extension of RDT&E flight testing and incorporation of early production aircraft into the flight test program. These schedules are not shown.

(U) In the process of scheduling flight test programs for ISADS, the overriding considerations were Rockwell test needs and the requirements called out in applicable Air Force specifications. For each design, 6 months of flight testing for A/C-1 is scheduled prior to long-lead go-ahead for Lot I. The number of production aircraft scheduled for ISADS flight testing varies in accordance with anticipated testing complexity and differences in specified performance. Schedules for refurbishment and redelivery of flight test A/C-5 and subsequent are included in the ISADS master program schedules.

(U) Separate complexity factors were established for the purpose of adjusting the B-1 master program schedule to make it consistent with ISADS requirements. For example, in the case of the low-cost concept (D645-1), ISADS engineering activities were compressed to 75 percent of the time required for comparable activities on the B-1. Other complexity factors were developed for application to manufacturing, associate contractor, and major subcontractor activities. Hardware deliveries were adjusted accordingly. In the event that firm schedules are required for ISADS at some future time, designated associate contractors and selected subcontractors would have to be consulted to determine precise leadtimes.

(U) B-1 production rates and deliveries were planned for buildup from one to a maximum of four aircraft per month. The planned rate buildup from one to four aircraft would have taken 32 months. Similar rate buildup schedules were established for the ISADS conceptual designs. The B-1 planned maximum production rate of four aircraft per month was used in every case for the ISADS designs.

(U) Initial operational capability (IOC) for the B-1 was planned to coincide with delivery of the 65th airplane. This figure was also used in the case of the ISADS designs. ISADS scheduled IOC dates are as follows:

Design Concept	IOC
Low cost (D645-1)	31 May 1995
Minimum weight (D645-6)	31 August 1994
Minimum penetration time (D645-3)	31 May 1996
Stealth (D645-4)	30 April 1995
Defensive laser (D645-5)	30 April 1996

Section VI

CONCLUSIONS AND RECOMMENDATIONS

(U) The objective of this study was to identify alternate approaches to preliminary designs of strategic aircraft through the application of innovative concepts and the most effective combinations of advanced technology. The study included projections in which advanced technologies applicable to 1995 manned penetrating bombers were identified and assessed. The surviving technologies were then integrated into five baseline aircraft concepts, upon which performance trades, cost, and program planning was accomplished.

ADVANCED TECHNOLOGIES

(U) Technologies which will be available for inclusion into a 1995 manned strategic penetrator can be expected to produce up to 50-percent total reductions in takeoff gross weight and cost for a given mission when compared to the best of current technology aircraft. This reduction will be produced by individual technology percent reductions as follows:

1. Structures - 30%
2. Propulsion - 25%
3. Aerodynamics - [i.e., Fuel Weight] - 40%
4. Equipment and misc. - 20%

(U) Structural weight reductions will occur mainly through the use of composite primary structure, aeroelastic tailoring, and superplastic-formed/diffusion-bonded (SPF/DB) titanium. Large one-piece components will reduce fasteners and joint structure, resulting in cost as well as weight savings. More exotic concepts such as metal matrix composites and SPF/DB aluminum will be beginning to see use by 1995, much as composites are today.

(U) Five propulsion-related items could have significant impact on an advanced strategic penetrating aircraft; i.e., fuels, engine weight and performance, variable-cycle engines, nuclear power, and 2-D nozzles.

(U) Petroleum based or synthetic JP fuels are likely to be the cheapest and most available fuels well into the next century and will therefore be the most likely fuel for the new aircraft. The trade study using liquid hydrogen showed that even though hydrogen has a much higher heat content per unit weight, the increased volume and structure required more than offset the reduced fuel weight. An extrapolation of this trend implies that a denser fuel than JP4, such as Shelldyne, could result in a takeoff gross weight reduction. While Shelldyne is currently very expensive because of a low production rate, and hence was not considered, it may become competitive with a high production rate. (U)

(U) Advances in engine materials and component performance will result in improved engine thrust-to-weight ratios and lower fuel consumption. A particularly promising area is that of ceramic combustors and turbines which will allow higher turbine inlet temperatures (with less turbine cooling flow) than currently achievable.

(U) Two-dimensional nozzles will provide vectoring for control and reduced IR/RCS.

(U) Variable-cycle engines hold promise for aircraft with widely varying performance requirements such as those of the minimum-time penetrator. Indeed, in order to achieve a reasonable takeoff gross weight for the minimum-time penetrator, it was necessary to have a variable-cycle engine. While a VABI was used in this study, the MMIPS or VSCE are also good candidate engines for such aircraft.

(U) While a nuclear-powered aircraft would require a vigorous development program and would probably face considerable environmentalist opposition, it does appear technically feasible.

(U) Two major advantages for the nuclear aircraft are (1) essentially infinite range and flight duration resulting in greater flexibility, and (2) reduced IR signature because there are no combustion products in the engine exhaust. Shielding of the reactor will minimize crew exposure and increase useful flight duration.

(U) The aerodynamic-related items primarily direct attention to the drag reduction concept. Reduction of turbulent skin friction drag offers the most fruitful area for significant progress. Included are techniques to eliminate roughness by application of surface coatings, delaying transition from laminar to turbulent flow by active boundary layer control in the near term, and by understanding the mechanism of transition and proper design in the far term. A 20-percent reduction in turbulent skin friction drag is projected. Additional advances in supercritical wing technology can be projected, resulting in a 15-percent reduction in lifting surface drag or the ability to operate at higher mach numbers without drag increases above current technology. Induced drag tailoring for this class of vehicles offers lower potential due to the considerable effort over the past decade to design efficient cruising wing geometries. However, a 5-percent reduction in induced drag is projected.

(U) While equipment is beyond the scope of the ISADS study, improvements will definitely occur by the year 2000. For example, a recently developed concept in avionic electromagnetic pulse (EMP) protection will allow a 1,600-pound savings over the equipment used in the B-1. (U)

(U) Stealth technologies will minimize aircraft observables in radar cross section, infrared radiation, and visual detection. Other observables such as laser cross section will become increasingly important in the year 1995 and beyond. Several techniques are available to address either the reflection (away from the receiver) or the absorption of these energy sources. The radar-absorbing materials (RAM) will find increasing use in areas of high reflectivity. However, advances are to be expected in this material to increase the frequency range of the absorption. Geometry control will continue to play an important role in inducing specular return away from the receiver. Tuned (selective frequency) radomes will be another development maturing in the 1995 timeframe.

(U) Computational technology advances will be in the forefront of these developments. Computational tools will enable the designer to advance his capabilities in an efficient manner and open the spectrum to additional applications. The aerospace industry will develop synthesis capability for 3-D nonlinear solutions with viscosity and expand to nonlinear flutter, divergence, and load analysis. In the far term, the operational capability to solve the Navier-Stokes equations will permit complex design computations currently unthinkable.

(U) Control technologies will continue to reflect the reduced static stability redundant control systems currently emerging. Ride control, gust load relief, and fatigue rate reduction have been demonstrated by structural mode control devices. Future systems will incorporate maneuver load control and active flutter suppression to enhance vehicle flight envelopes at reduced structure weight.

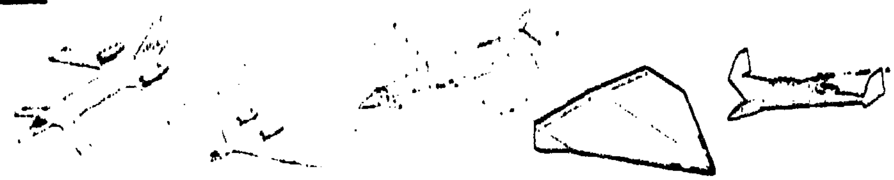
(U) A development cost study of these technologies was not a part of this study, as this is available in Reference 16.

(U) Figure 127 summarizes the ISADS configuration baseline concepts. Figure 128 shows a relative size comparison of the concepts.

(U) Note that four of the five baseline concepts benefit from the structural simplicity of the all-wing arrangement, which can be used to best advantage due to the large fuel volume required to perform the ISADS mission. Also, the geometric simplicity of the all-wing design tends to yield a lower radar cross section.

(U) The major risk of the all-wing arrangement is in the provision of adequate stability and control without incurring a performance degradation. Previous all-wing designs have incorporated reflexed airfoils and/or highly twisted wings to attain longitudinal trim and stability, with resulting efficiency losses. The adaptation of advanced flight controls to the all-wing

CONCEPT CONCLUSIONS



	LOW COST	MINIMUM WEIGHT	MINIMUM PENETRATION TIME	STEALTH	LASER DEFENSE
TOGW	312883	292870	551880	302396	340808
PAYLOAD	50,000	50,000	50,000	50,000	50,000
FUEL WEIGHT	156214	150818	325421	164882	159718
CRUISE MACH NO.	0.85	0.85	0.81	0.85	0.85
CRUISE ALTITUDE*	29K/50K	29K/50K	20K/42K	23K/48K	29K/48K
PENETRATION MACH NO.	0.72	0.72	1.2	0.72	0.72
PENETRATION ALTITUDE	200 FT	200 FT	200 FT	200 FT	200 FT
WITHDRAWAL MACH NO.	0.8	0.8	0.84	0.8	0.8
WITHDRAWAL ALTITUDE	200 FT	200 FT	200 FT	200 FT	200 FT

* START OUTBOARD CRUISE/END RECOVERY CRUISE

SECRET

(S) Figure 127. Baseline concepts summary. (U)

concept should enable the elimination of most of the losses. However, the technical risk involved prevented application of the all-wing concept to the ISADS low cost simplistic baseline. (U)

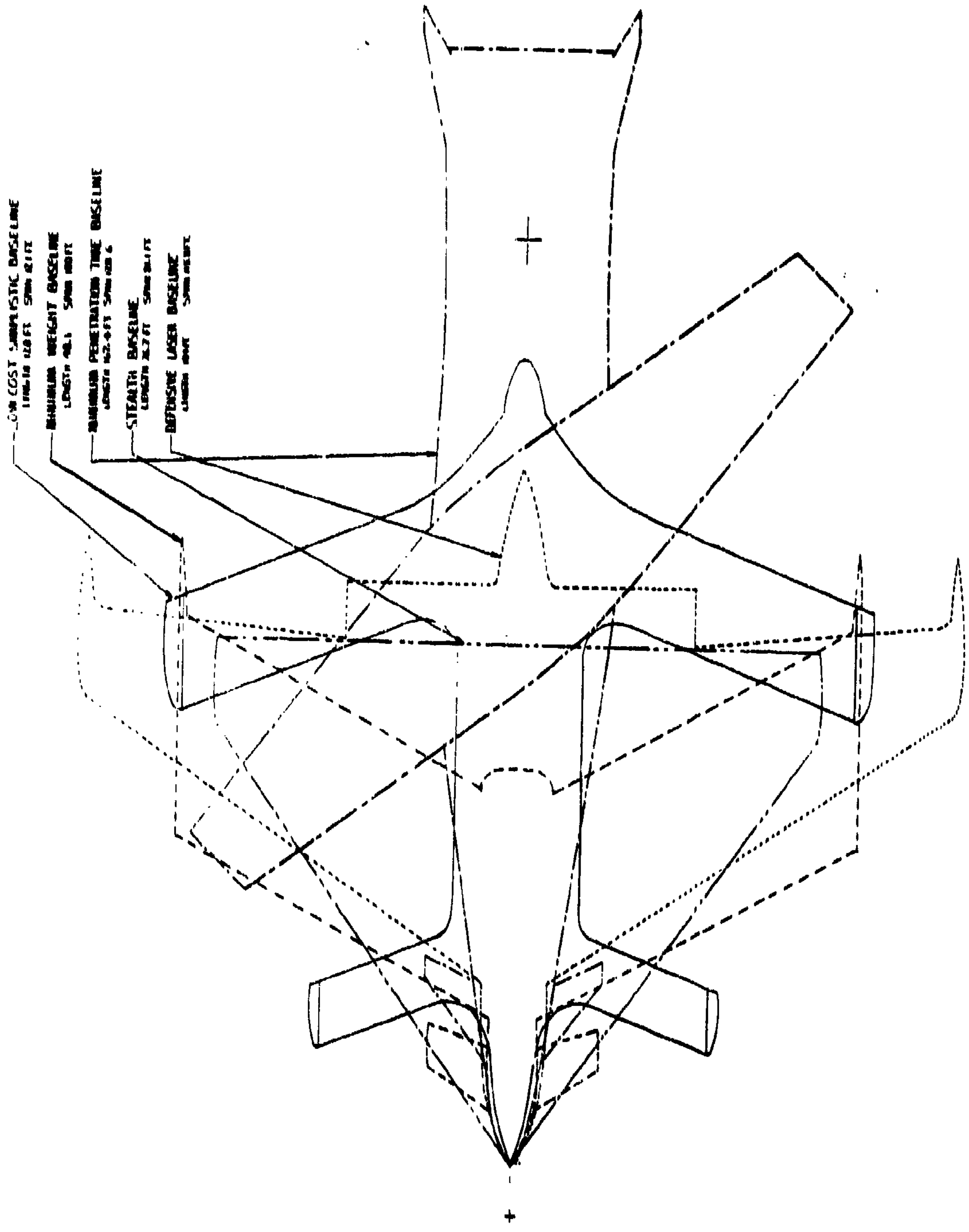
(U) The major conceptual conclusions are as follows.

LOW-COST SIMPLISTIC

(U) The major conclusion from this effort is that a simplistic, minimum risk aircraft may incur efficiency penalties sufficient to raise the total system cost over that of a less simple, more efficient aircraft. However, the simplistic approach offers minimum program risk, and is not dependent on unproven technologies.

MINIMUM WEIGHT

(U) The spanloader concept produced a very light aircraft when aided by the use of a canard trimmer. Although alternatives of external stores were investigated, the lowest weight approach was to accept a structural penalty to retain clean aerodynamics.



(U) Figure 128. Relative size comparisons. (U)

MINIMUM PENETRATION TIME

(U) Supersonic penetration on the deck for 1,750 nautical miles was shown to be viable, but a high risk. This is because of the advanced technology development required to attain the high-speed penetration efficiency yet still accomplish high-altitude transitional cruise out and back

STEALTHY

(S) The "flying delta wing concept" proved to be a very stealthy system for the penetrator case. It gave up less than 5 percent in weight when compared with the minimum-weight concept. First-order approximations show the concept to have an average radar cross section between 0.01 and 0.1 square meters. It also proved to be the smallest aircraft with advantages in manufacturing, maintenance, and survivability. Potential problems include possible unusual stability characteristics and low accessibility of internal systems.

LASER DEFENSE

(U) Carriage of a laser lethal defense system was shown to be compatible with the ISADS mission. Further study should investigate its value relative to a substantial system weight penalty. Trades assessing additional defensive missiles/guns with substantial additional fuel must be addressed.

COST

(U) The major cost conclusion is that cost is still primarily a function of weight. Thus, weight-reducing advanced technology will usually reduce the aircraft cost, in spite of the increased cost and complexity of that technology. However, those unproven, advanced technologies increase the cost uncertainty and therefore increase the probability of a cost overrun.

(U) Further, the actual cost of any manned strategic penetrator will be largely fixed at the earliest stages of procurement, in which the mission requirements are established. Especially important parameters are range, payload, speed, altitude, refueling, and avionics. These establish subsystems requirements, which, in turn, establish 60 to 70 percent of the aircraft cost.

RECOMMENDATIONS

(U) The following recommendations are suggested:

1. Mission requirements for a manned strategic aircraft should be established by effectiveness/cost/risk trade studies, in which the evaluation parameter is target value killed versus cost of the system.

Suggested studies include:

a. Standoff versus penetrating

b. Avionics/ECM requirements

c. Payload versus force size

d. Lethal defense effectiveness

e. Launch survival concepts

2. Additional aircraft concepts should be investigated:

a. Multirole aircraft

b. Laser gunship

c. Surface effect

3. Additional trade studies should be undertaken to use the ISADS data base:

a. Mission trades (range, speeds, payload, mission profile, conventional uses)

b. Engine trades (number, type, BPR)

c. Avionics/ECM trades

d. Other subsystem trades relative to total system cost/risk/effectiveness

e. Technology level trade (vary IOC date - 1985, 1990, 1995) (U)

Section VII

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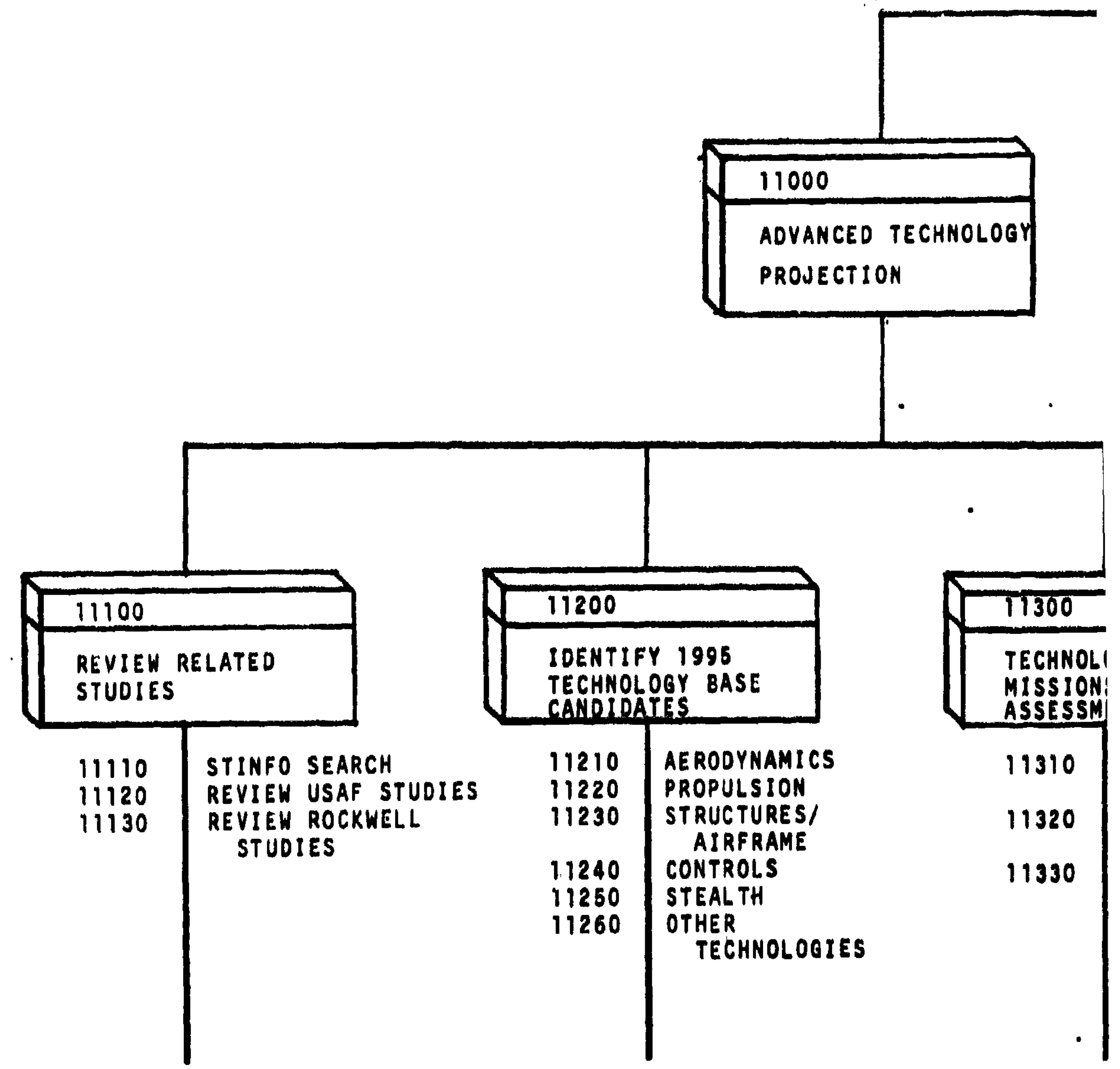
Appendix A

PROGRAM WORK BREAKDOWN


11000
ADVANCED TECHNOLOGY
PROJECTION
11100
REVIEW RELATED STUDIES
11110 STINFO SEARCH
11120 REVIEW USAF STUDIES
11130 REVIEW ROCKWELL STUDIES
11200
IDENTIFY 1995 TECHNOLOGY BASE CANDIDATES
11210 AERODYNAMICS
11220 PROPULSION
11230 STRUCTURES/ AIRFRAME
11240 CONTROLS
11250 STEALTH
11260 OTHER TECHNOLOGIES
11300
TECHNOL
MISSION
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11330

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ONS/
SMENT

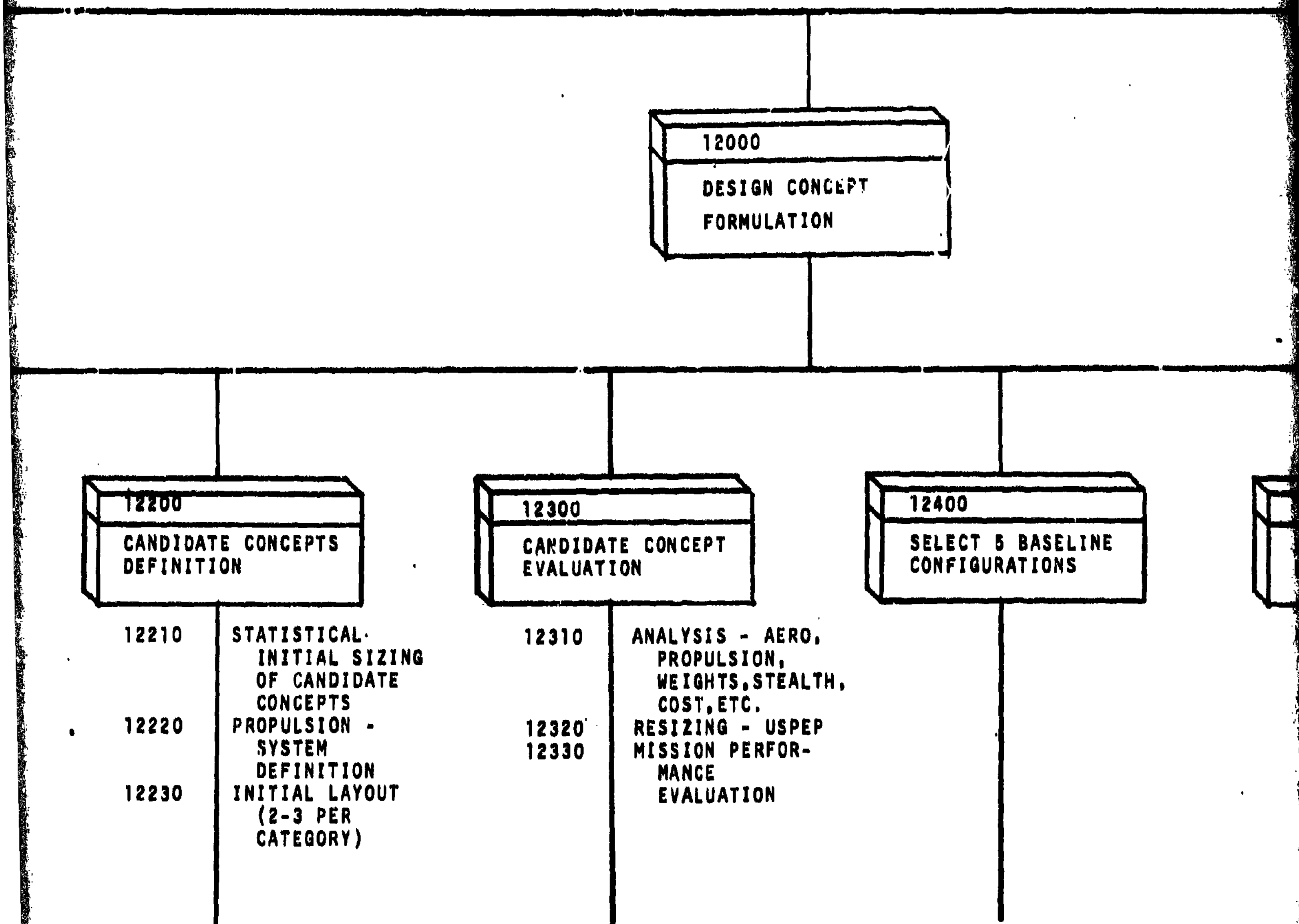
MISSION PARAMETERS IMPACT
COST/RISK ASSESSMENT
ADDITIONAL FACTORS ASSESSMENT

11400
AIRESEARCH PROPULSION TECHNOLOGY CONCEPTS

11410	CONSTANT VOLUME COMBUSTION ENGINES
11420	VARIABLE CYCLE ENGINES
11430	COMPOUND ENGINES
11440	HYDROGEN FUELED ENGINES
11450	RECUPERATED CYCLES
11460	HIGH MACH NUMBER TURBOPROPS
11470	BOUNDARY LAYER INGESTION

12100
INITIAL DESIGN CONCEPTS

12110	CONCEPTUAL SKETCHES (6 PER CATEGORY)
12120	CONCEPT RANKING & SELECTION (2-3 PER CATEGORY)


12000
DESIGN CONCEPT FORMULATION
12200
CANDIDATE CONCEPTS DEFINITION
12210 STATISTICAL INITIAL SIZING OF CANDIDATE CONCEPTS
12220 PROPULSION - SYSTEM DEFINITION
12230 INITIAL LAYOUT (2-3 PER CATEGORY)
12300
CANDIDATE CONCEPT EVALUATION
12310 ANALYSIS - AERO, PROPULSION, WEIGHTS, STEALTH, COST, ETC.
12320 RESIZING - USPEP
12330 MISSION PERFORMANCE EVALUATION
12400
SELECT 5 BASELINE CONFIGURATIONS

12500
DEVELOP DESIGN LAYOUTS

- 12510 DETAILED LAYOUT OF 5 BASELINE CONFIGURATIONS
- 12520 CONFIGURATION CHARACTERISTICS DESCRIPTIONS

12600
AIRESEARCH PROPULSION DATA

- 12610 PROVIDE TECHNOLOGY CONCEPT DOCUMENTATION
- 12620 EVALUATE CONCEPTUAL SKETCHES' PROPULSION INTEGRATION
- 12630 EVALUATE CANDIDATE CONCEPT LAYOUTS
- 12640 EVALUATE BASELINE LAYOUTS AND SUPPLY PROPULSION CHARACTERISTICS WRITE-UP

13100
DESIGN TRADES/ OPTIMIZE

- 13110 TRADE STUDY MATRIX SELECTION
- 13120 PERTURBED C FIGURATI DEFINITI
- 13130 RESIZE AND OPTIMIZE PERTURBE CONFIGURATIONS
- 13140 EVALUATE T FOR TOTAL IMPACT

13000
BASELINE REFINEMENT

13200 — FINAL DESIGN LAYOUTS, CHARACTERISTICS

- 13210 FINAL DESIGN LAYOUTS
- 13220 ASSUMPTIONS, CHARACTERISTICS, AND GEOMETRY DEFINITION
- 13230 IDENTIFY NEEDED TECHNOLOGICAL ADVANCES

13300 — PERFORMANCE ANALYSIS

- 13310 MISSION PERFORMANCE
- 13320 T.O. & LANDING
- 13330 MANEUVERING

14100 — RDT&E (ANALYS

- 14110
- 14120
- 14130

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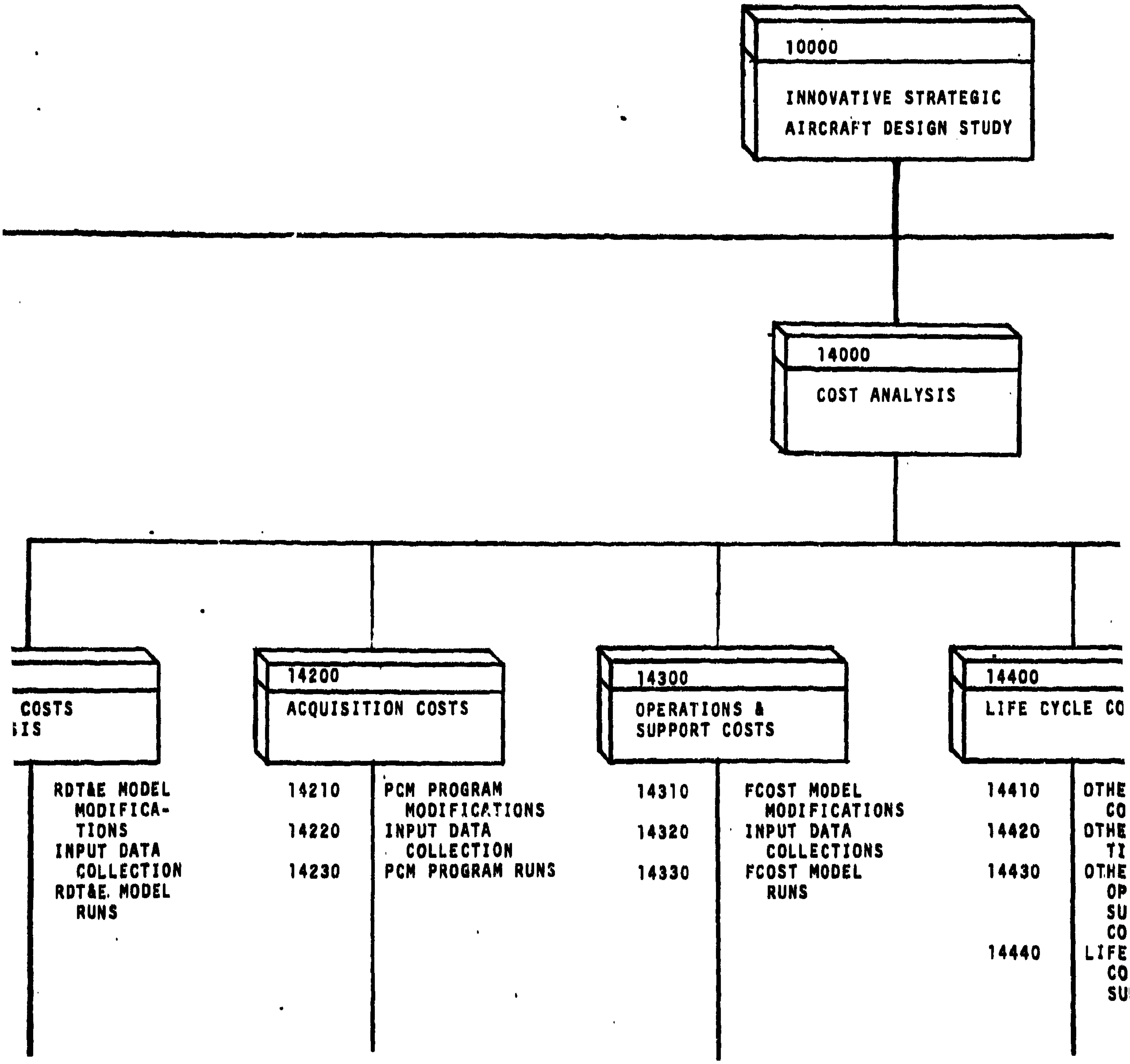
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COST ANALYSIS
COSTS
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RDT&E MODEL MODIFICATIONS
INPUT DATA COLLECTION
RDT&E MODEL RUNS
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ACQUISITION COSTS
14210 PCM PROGRAM MODIFICATIONS
14220 INPUT DATA COLLECTION
14230 PCM PROGRAM RUNS
14300
OPERATIONS & SUPPORT COSTS
14310 FCOST MODEL MODIFICATIONS
14320 INPUT DATA COLLECTIONS
14330 FCOST MODEL RUNS
14400
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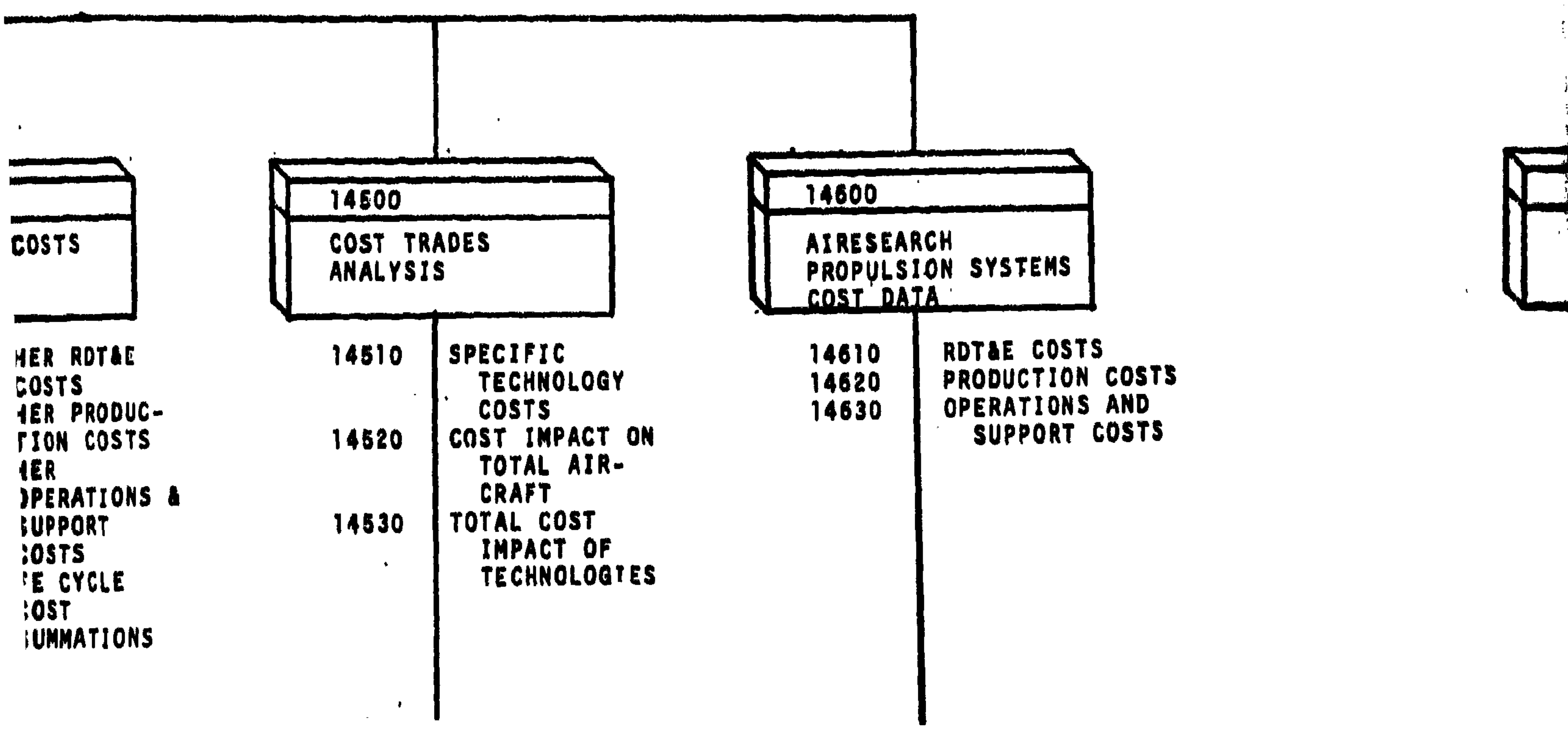
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HER RDT&E
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OPERATIONS &
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COSTS
E CYCLE
COST
SUMMATIONS
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COST TRADES ANALYSIS
14510 SPECIFIC TECHNOLOGY COSTS
14520 COST IMPACT ON TOTAL AIR-CRAFT
14530 TOTAL COST IMPACT OF TECHNOLOGIES
14600
AIRESEARCH PROPULSION SYSTEMS COST DATA
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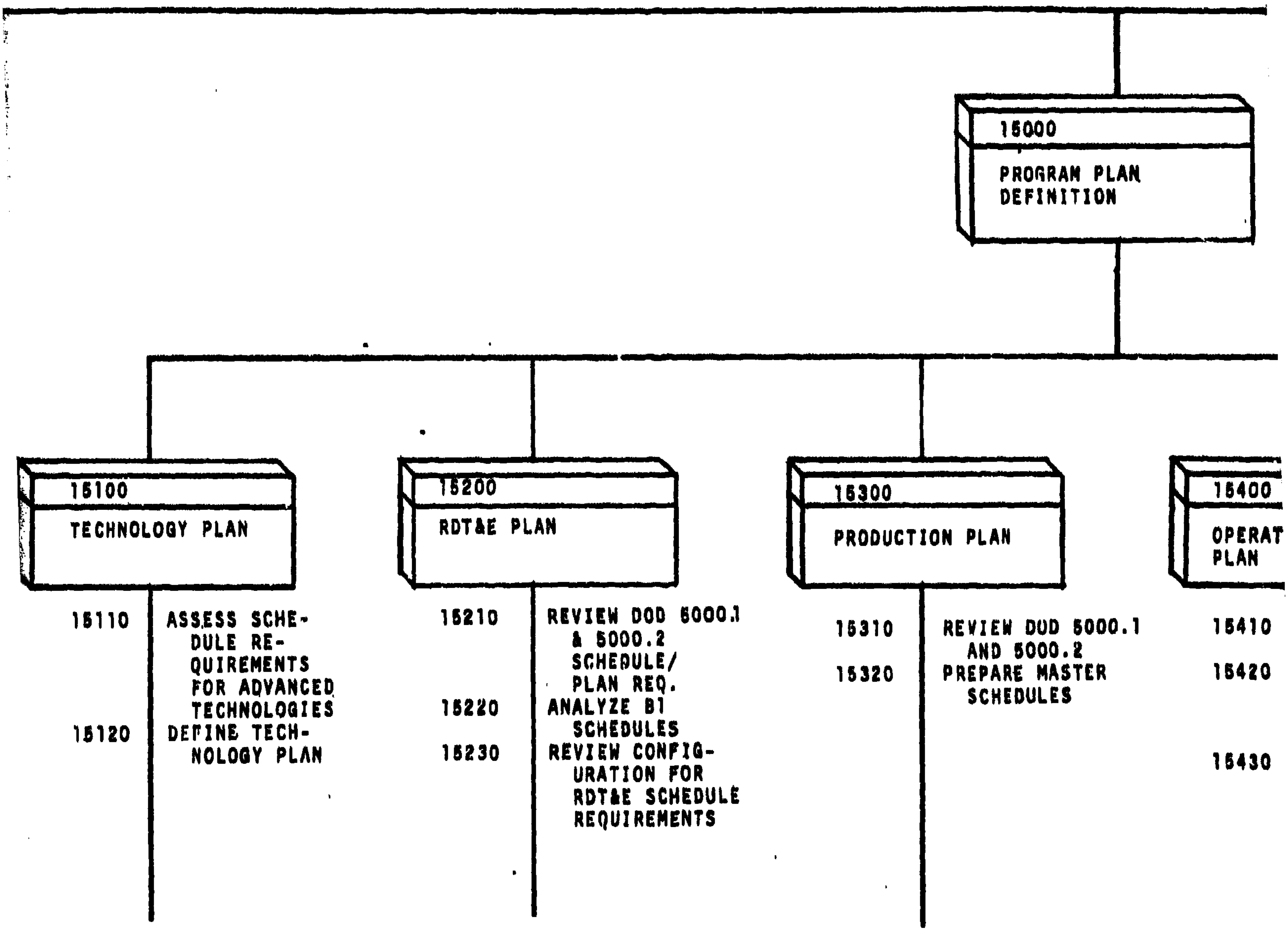
14620 PRODUCTION COSTS
14630 OPERATIONS AND SUPPORT COSTS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TECHNOLOGY PLAN
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15120 DEFINE TECHNOLOGY PLAN
15200
RDT&E PLAN
15210 REVIEW DOD 5000.1 & 5000.2 SCHEDULE/PLAN REQ.
15220 ANALYZE B1 SCHEDULES
15230 REVIEW CONFIGURATION FOR RDT&E SCHEDULE REQUIREMENTS
15300
PRODUCTION PLAN
15310 REVIEW DOD 5000.1 AND 5000.2
15320 PREPARE MASTER SCHEDULES
15400
OPERAT
PLAN
15410
15420
15430

00

RATIONS SUPPORT

10 REVIEW CURRENT BOMBER O&S

20 IDENTIFY SUPPORT HARDWARE & FACILITIES REQUIREMENTS

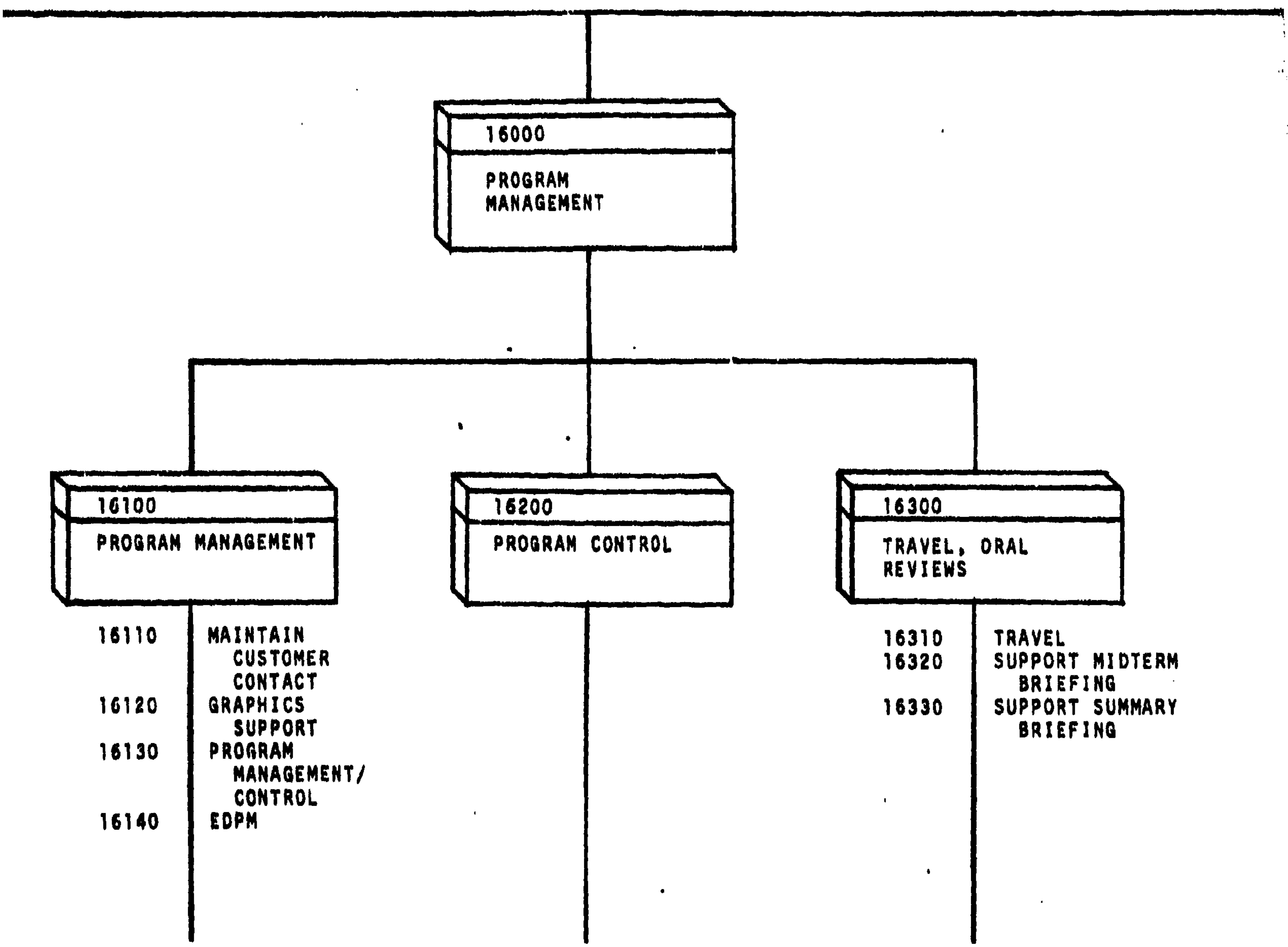
0 PREPARE O&S PLAN

15500

USAF/DOD REVIEWS/ APPROVALS SCHEDULE

15600

AIRESEARCH PROPULSION SYSTEM TECHNOLOGY, DEVELOPMENT, PRODUCTION PLANS DATA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16140 EDPM
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PROGRAM CONTROL
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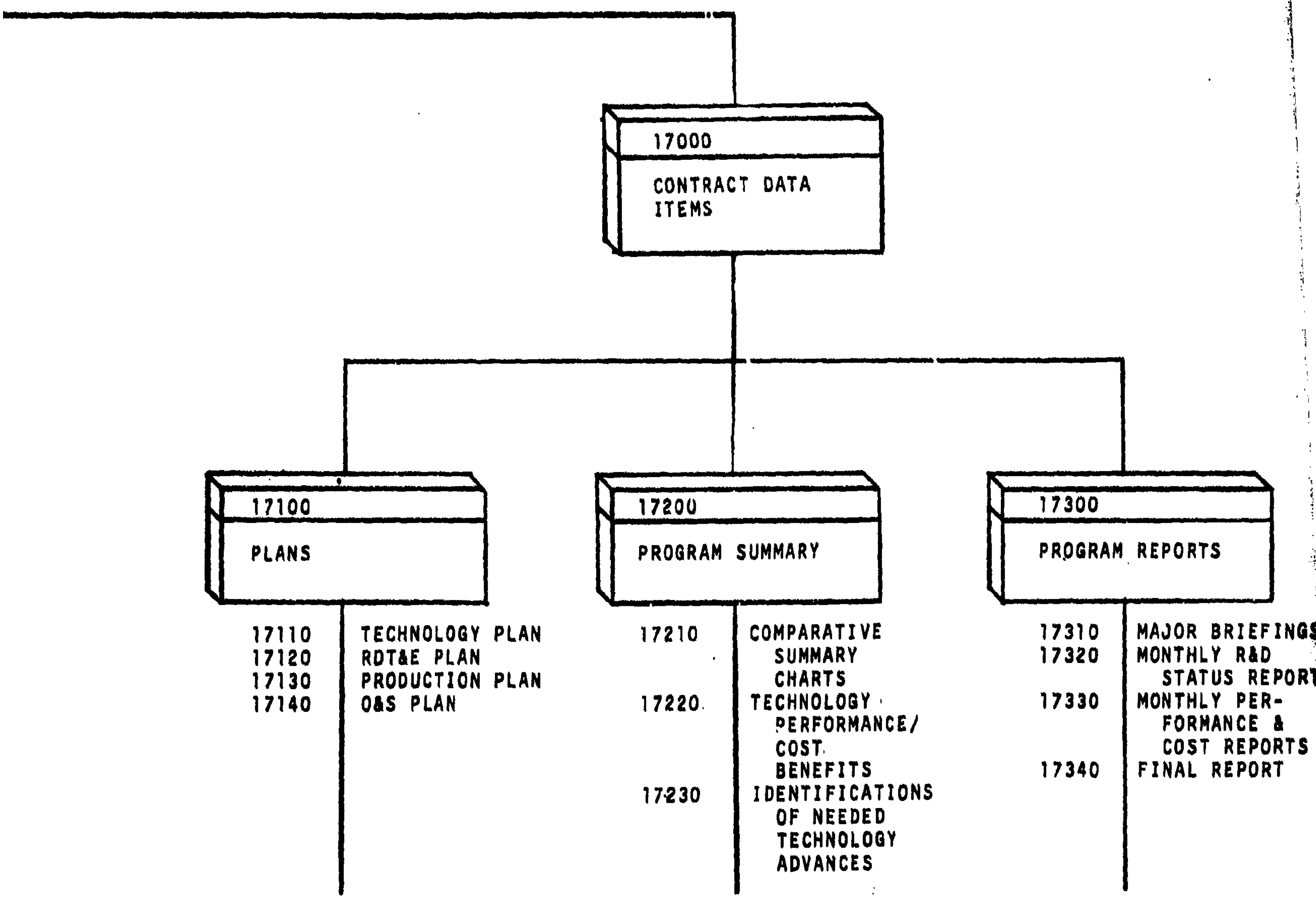
TRAVEL, ORAL REVIEWS
16310 TRAVEL
16320 SUPPORT MIDTERM BRIEFING
16330 SUPPORT SUMMARY BRIEFING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PROGRAM SUMMARY
17210 COMPARATIVE SUMMARY CHARTS
17220 TECHNOLOGY PERFORMANCE/ COST BENEFITS
17230 IDENTIFICATIONS OF NEEDED TECHNOLOGY ADVANCES
17300
PROGRAM REPORTS
17310 MAJOR BRIEFINGS
17320 MONTHLY R&D STATUS REPORT
17330 MONTHLY PERFORMANCE & COST REPORTS
17340 FINAL REPORT

(U) Figure A-1.

RAYMER
12 OCT 77

Rockwell International Corporation
Los Angeles Aircraft Division
INTERNATIONAL AIRPORT LOS ANGELES, CALIFORNIA 90009

WORK BREAKDOWN STRUCTURE
ISADS

. ISADS work breakdown structure. (U)

Appendix B

CONCEPT SELECTION DATA

(U) CONFIGURATION CONCEPT QUALITATIVE RATING FORM (U)

INSTRUCTIONS

1. Assign numerical ratings (0-9) based on the following scale to the evaluation parameters listed for your discipline (only). These ratings are to be relative judgments of the aircraft concepts in a given category. A higher rating should always indicate a more desirable impact on the aircraft; i.e., more mission capability, less weight, less cost, more stealth, etc.

2. On a separate page, attach any comments that may help in selecting the best (or worst) concepts. Also, list any specific assumptions you made to do the evaluation.

3. Return to D. Raymer (X3451) after each rating.

0	1	2	3	4	5	6	7	8	9
Totally Unacceptable				Average of concepts in that category				Ideal case	

Configuration Concept Qualitative Rating Form

Category: Low cost - 1		Concept number						
Group	Evaluation parameter	1-1	1-2	1-3	1-4	1-5	1-6	1-7
Aerodynamics	Cruise drag	5	6	6	6	6	4	7
	Penetration drag	5	3	2	3	4	3	1
	Low-speed flight	6	4	6	6	6	6	8
	Flight control	6	6	6	3	5	6	4
Propulsion	Complexity	7	6	2	7	4	1	1
	Efficiency	3	3	5	3	6	9	9
	Installed weight	1	1	5	1	6	7	7
Weights	Loads	5	5	5	5	3	5	3
	Strength requirements	5	4	4	4	8	5	3
	Load paths	6	3	3	3	4	5	5
M&P	Producibility	8	4	4	3	3	2	8
Structures	Structural risk	4	5	3	3	5	3	5
	Design Producibility	8	4	3	3	7	3	8
	Materials cost & risk	7	8	5	7	7	3	8
Stealth	RCS	1	2	2	0	0	0	0
	IR signature	2	7	8	2	3	5	4
Performance	T.O. & landing	6	6	6	6	6	6	6
	Maneuver	5	5	5	5	5	1	3
	Fuel weight							
	TOGW	5	4	3	4	5	3	3
OPS analysis	Support requirements	6	6	4	5	5	1	2
	Survival/vulnerability	6	6	3	6	6	1	0
	Flyaway cost	6	5	3	6	6	0	1
	O&S cost	6	6	3	5	5	1	1

* Note: 0-9 scale, higher number is "better"

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Configuration Concept Qualitative Rating Form

Category: Minimum weight - 2		Concept number							
Group	Evaluation parameter	1	2	3	4	5	6	7	8
Aerodynamics	Cruise drag	8	8	4	7	7	7	4	8
	Penetration drag	5	5	2	6	6	4	4	4
	Low-speed flight	7	7	5	6	6	6	5	8
	Flight control	2	2	2	7	7	2	3	5
Propulsion	Complexity	7	8	2	7	2	5	3	7
	Efficiency	3	6	5	3	6	3	7	3
	Installed weight	1	8	4	1	8	1	5	2
Weights	Loads	6	6	6	4	4	4	5	5
	Strength requirements	6	6	6	4	4	4	5	6
	Load paths	6	6	6	4	4	4	4	6
M&P	Producibility	3	3	2	3	4	3	3	3
Structures	Structural risk	7	3	4	5	2	4	3	3
	Design Producibility	7	2	7	3	3	8	3	3
	Materials cost & risk	7	4	6	5	3	3	5	3
Stealth	RCS	0	0	2	1	1	1	1	0
	IR signature	4	4	6	7	8	8	1	2
Performance	T.O. & landing	5	5	4	6	6	4	4	5
	Maneuver	5	5	6	5	4	1	5	1
	Fuel weight								
	TOGW	6	6	3	5	5	4	4	4
OPS analysis	Support requirements	5	4	4	5	4	1	5	0
	Survival/vulnerability	6	4	5	6	5	4	6	1
	Flyaway cost	5	3	3	5	3	2	5	0
	O&S cost	6	4	3	6	4	3	6	0

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Configuration Concept Qualitative Rating Form

Category: Minimum penetration + 3		Concept number					
Group	Evaluation parameter	1	2	3	4	5	6
Aerodynamics	Cruise drag	6	5	5	6	6	6
	Penetration drag	6	8	8	5	6	6
	Low speed flight	6	4	4	4	8	6
	Flight control	3	3	3	3	5	5
Propulsion	Complexity	4	3	4	4	3	3
	Efficiency	4	5	4	4	5	5
	Installed weight	5	4	5	5	4	4
Weights	Loads	5	5	5	4	5	5
	Strength requirements	6	5	5	5	7	7
	Load paths	5	5	5	4	7	7
M&P	Producibility	4	3	2	2	2	8
Structures	Structural risk	3	3	4	3	4	4
	Design producibility	5	5	4	4	3	3
	Materials cost & risk	3	5	4	4	4	4
Stealth	RCS	1	8	3	8	8	8
	IR signature	8	6	8	8	8	8
Performance	T.O. & landing	5	3	4	4	6	6
	Maneuver	8	3	4	4	5	5
	Fuel weight						
	TOGW						
OPS analysis	Support requirements	5	5	5	5	5	5
	Survival/vulnerability	5	7	6	5	5	5
	Flyaway cost	5	4	3	2	7	7
	O&S	6	5	5	5	7	7

UNCLASSIFIED

Configuration Concept Qualitative Rating From

Category: Stealthy + 6		Concept number					
Group	Evaluation parameter	1	2	3	4	5	6
Aerodynamics	Cruise drag	5	6	5	6	5	6
	Penetration drag	8	8	3	5	5	7
	Low speed flight	4	6	5	5	6	6
	Flight control	3	4	3	3	5	1
Propulsion	Complexity	7	7	3	3	7	7
	Efficiency	3	3	5	5	3	3
	Installed weight	2	2	4	4	2	2
Weights	Loads	5	5	7	5	6	3
	Strength requirements	5	5	6	5	5	6
	Load paths	5	5	7	6	5	8
M&P	Producibility	4	4	3	4	4	6
Structures	Structural risk	3	5	6	5	5	2
	Design producibility	6	6	6	5	5	5
	Materials cost & risk	5	5	5	5	5	6
Stealth	RCS	7	6	8	7	6	5
	IR signature	6	8	6	5	5	8
Performance	T.O. & landing	3	5	4	4	5	3
	Maneuver	4	5	6	5	5	4
	Fuel weight						
	TOGW						
OPS analysis	Support requirements	5	5	5	5	5	3
	Survival/vulnerability	6	5	5	6	6	8
	Flyaway cost	5	5	6	6	6	3
	O&S cost	5	5	5	5	5	6

UNCLASSIFIED

Configuration Concept Qualitative Rating Form

Category: LaaP + 3		Concept number						
Group	Evaluation parameter	1	2	3	4	5	6	7
Aerodynamics	Cruise drag	6	6	6	5	6	5	4
	Penetration drag	5	5	5	4	6	4	4
	Low speed flight	4	4	4	5	4	5	5
	Flight control	2	8	3	8	6	8	1
Propulsion	Complexity	4	4	3	3	4	7	4
	Efficiency	6	6	6	6	5	3	6
	Installed weight	5	5	4	4	6	1	8
Weights	Loads	5	5	5	7	5	7	5
	Strength requirements	6	6	6	7	4	7	4
	Load paths	5	8	6	7	4	7	4
M&P	Producibility	4	4	4	3	3	4	3
Structures	Structural risk	6	6	5	4	3	5	3
	Design producibility	5	5	5	3	3	5	3
	Materials cost & risk	5	5	5	5	5	5	4
Stealth	RCS	1	1	6	2	1	2	1
	IR signature	4	4	4	2	3	4	5
Performance	T.O. & landing	4	4	4	5	5	4	4
	Maneuver	5	5	5	3	5	3	4
	Fuel weight							
	TOGW							
OPS analysis	Support requirements	8		5	5	5	4	5
	Survival/vulnerability	6		5	7	8	5	4
	Flyaway cost	8		8	5	6	3	6
	O&S cost	8		5	6	5	8	4

UNCLASSIFIED

Category: low cost	Concept number		
Parameter	1-1	1-2	1-4
Aerodynamics			
L/D MAX for optimum cruise	19	20	16
L/D at penetration mach number and altitude	8	7	10
L/D at withdrawal mach number and altitude	10.5	10	11.5
Propulsion			
SFC for optimal cruise	.60	.60	.60
SFC for penetration mach number and altitude	.82	.82	.82
SFC for withdrawal mach number and altitude	.70	.70	.70
SFC for sea-level loiter (≈0.3M)	.65	.65	.65
Mass properties			
W_{empty}/W_o - empty weight fraction	.31	.31	.31
W_{fix} - Weight of fixed equipment items necessary to perform desired task	81,376	81,376	81,376
Sized vehicle			
W_o - gross weight	395,000	425,000	407,500
W_{fuel} - fuel weight	191,020	211,440	199,640
W_{fuel}/W_o - fuel fraction	.4836	.4975	.4899

UNCLASSIFIED

(U) Sizing parameters estimation form.(U)

(Note: These are statistically based estimates)

Concept: low cost

Range = 5,250 n mi
TOGW = 395,000 lb

Mission segment	Current technology baseline: M	L/D	SFC	M L/D / SFC	ΔR	ΔWF
WU + T.O.	-	-	-	-	-	2,774
CLI + CRUS	0.72	18.5	0.760	17.526	3,000	101,027
PEN.	0.72	10.1	0.906	8.026	1,000	52,964
WITH.	0.66	11.7	0.897	7.304	750	32,754
CLI + CRUS	0.72	18.5	0.760	17.526	500	13,168
LOITER	-	18.5	0.767	24.120	-	3,987
RES	-	-	-	-	-	8,169
Total					5,250	214,849
Fuel fraction reqd					0.5439	

Mission segment	1-1: M	L/D	SFC	M L/D / SFC	ΔR	ΔWF
WU + T.O.	-	-	-	-	-	2,774
CLI + CRUS	0.72	19.0	0.60	22.800	3,000	77,658
PEN.	0.72	8.0	0.82	7.024	1,000	60,518
WITH.	0.56	10.5	0.70	8.400	750	28,480
CLI + CRUS	0.72	19.0	0.60	22.800	500	10,125
LOITER	-	19.0	0.65	29.231	-	3,290
RES	-	-	-	-	-	8,169
Total					5,250	191,011
Fuel fraction reqd					0.4836	

Mission segment	1-2: M	L/D	SFC	M L/D / SFC	ΔR	ΔWF
WU + T.O.	-	-	-	-	-	2,774
CLI + CRUS	0.72	20.0	0.60	24.000	3,000	73,775
PEN.	0.72	7.0	0.82	6.146	1,000	69,164
WITH.	0.56	10.0	0.70	8.000	750	29,904
CLI + CRUS	0.72	20.0	0.60	24.000	500	9,616
LOITER	0 -	20.0	0.65	30.769	-	3,125
RES	-	-	-	-	-	8,169
Total					5,250	196,527
Fuel fraction reqd					0.4971	

Mission segment	1-4: M	L/D	SFC	M L/D / SFC	ΔR	ΔWF
WU + T.O.	-	-	-	-	-	2,774
CLI + CRUS	0.72	16.0	0.60	19.200	3,000	92,219
PEN.	0.72	10.0	0.82	8.780	1,000	48,419
WITH.	0.56	11.5	0.70	9.200	750	26,004
CLI + CRUS	0.72	16.0	0.60	19.200	500	12,020
LOITER	-	16.0	0.65	24.615	-	3,907
RES	-	-	-	-	-	8,169
Total					5,250	193,508
Fuel fraction reqd					0.4899	

UNCLASSIFIED

Category: min weight	Concept number	
Parameter	2-1	2-6
Aerodynamics		
L/D MAX for optimum cruise	30	25
L/D at penetration mach number and altitude	7	25
L/D at withdrawal mach number and altitude	12	25
Propulsion		
SFC for optimal cruise	.60	.67
SFC for penetration mach number and altitude	.82	.67
SFC for withdrawal mach number and altitude	.70	.67
SFC for sea-level loiter (~0.3M)	.65	.65
Mass properties		
W_{empty}/W_o - empty weight fraction	.31	.31
W_{fix} - weight of fixed equipment items necessary to perform desired task	81,376	81,376
Sized vehicle		
W_o - gross weight	397,000	240,000
W_{fuel} - fuel weight	192,520	83,520
W_{fuel}/W_o - fuel fraction	.4849	.3480

UNCLASSIFIED

(U) Sizing parameters estimation form. (U)

Concept: min weight

Range = 6,250 nmi
TOGW = 395,000 lb

	Current Technology Baseline						2-1						2-6					
Mission Segment	M	L/D	SFC	ML/D SFC	ΔR	ΔWF	M	L/D	SFC	ML/D SFC	ΔR	ΔWF	M	L/D	SFC	ML/D SFC	ΔR	ΔWF
WU + TO	-	-	-	-	-	2,774	-	-	-	-	-	2,774	-	-	-	-	-	2,774
CLI + CRUS	0.78	18.6	0.760	17.520	3,000	101,027	0.78	30.0	0.60	14.000	3,000	73,775	0.86	25.0	0.67		5,250	126,016
PEN.	0.72	10.1	0.906	8.026	1,000	52,986	0.72	7.0	0.82	6.146	1,000	89,166						
WITH.	0.86	11.7	0.897	7.304	750	32,756	0.86	12.0	0.70	9.600	750	24,011						
CLI + CRUS	0.78	18.5	0.760	17.026	500	13,158	0.78	30.0	0.60	14.000	500	9,616						
LOITER	-	18.9	0.707	26.120	-	3,987	-	30.0	0.65	30.769	-	3,115	-	25.0	0.65	38.462	-	2,200
RES.	-	-	-	-	-	8,164	-	-	-	-	-	8,169	-	-	-	-	-	8,169
				Totals	5,250	214,046					5,250	191,545					5,250	137,469
				Fuel Fraction Req'd	0.5419						0.4849						0.3480	

UNCLASSIFIED

Category: high "Q" penetrator	Concept number		
Parameter	3-1	3-2	3-5
Aerodynamics			
L/D MAX for optimum cruise	18	20	18
L/D at penetration mach number and altitude	5	7.5	5
L/D at withdrawal mach number and altitude	10	12	10
Propulsion			
SFC for optimal cruise	0.65	0.65	0.65
SFC for penetration mach number and altitude	1.3	1.3	1.3
SFC for withdrawal mach number and altitude	0.7	0.7	0.7
SFC for sea-level loiter (~ 0.3M)	0.65	0.65	0.65
Mass properties			
W_{empty}/W_0 - empty weight fraction	.34	.36	.34
W_{fix} - weight of fixed equipment items necessary to perform desired task	75,987	75,987	75,987
Sized vehicle			
W_0 - gross weight	>800,000	510,000	>800,000
W_{fuel} - fuel weight		246,300	
W_{fuel}/W_0 - fuel fraction	.5995	.4829	.5995

UNCLASSIFIED

(U) Sizing parameters estimation form. (U)

Concept: Min. pen. (1.2M)

Range = 5,250 nmi
TOGW = 555,000 lb

	Current Technology Baseline						3-1						3-2					
Mission Segment	M	L/D	SFC	ML/D SFC	ΔR	ΔWF	M	L/D	SFC	ML/D SFC	ΔR	ΔWF	M	L/D	SFC	ML/D SFC	ΔR	ΔWF
WU + TO	-	-	-	-	-	2,774	-	-	-	-	-	2,774	-	-	-	-	-	2,774
ACC + CRUS	0.72	18.9	0.760	17.976	3,000	101,027	0.72	18.0	0.65	19.938	3,000	88,883	0.72	20.0	0.65	22.154	3,000	79,923
PEN.	0.72	10.1	0.906	8.015	1,000	52,966	1.2	5.0	1.3	4.615	1,000	92,106	1.2	7.5	1.3	6.013	1,000	61,606
WITH.	0.86	11.7	0.897	7.304	750	30,754	0.56	10.0	0.7	8,000	750	29,904	0.56	12.0	0.7	9.600	750	24,888
CLI + CRUS	0.72	18.5	0.760	17.836	500	13,160	0.72	18.0	0.65	19,938	500	11,878	0.72	20.0	0.65	22.154	500	10,417
LOITER	-	18.9	0.767	24.120	-	3,987	-	18.0	0.65	27.692	-	3,671	-	20.0	0.65	30.769	-	3,189
RES.	-	-	-	-	-	8,169	-	-	-	-	-	8,169	-	-	-	-	-	8,169
				Totals	5,250	214,849					5,250	236,806					5,250	190,737
				Fuel Fraction Req'd.	0.6419						0.5995						0.4829	

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Category: stealthy	Concept number		
Parameter	4-1	4-3	4-5
Aerodynamics			
L/D MAX for optimum cruise	16	20	16
L/D at penetration mach number and altitude	11	8	10
L/D at withdrawal mach number and altitude	12	10	12
Propulsion			
SFC for optimal cruise	.60	.60	.60
SFC for penetration mach number and altitude	.82	.82	.82
SFC for withdrawal mach number and altitude	.70	.70	.70
SFC for sea-level loiter (~ 0.3M)	.65	.65	.65
Mass Properties			
W_{empty}/W_o - empty weight fraction	.34	.34	.34
W_{fix} - weight of fixed equipment items necessary to perform desired task	75,987	75,987	75,987
Sized vehicle			
W_o - gross weight	414,000	412,000	436,000
W_{fuel} - fuel weight	197,070	195,950	212,380
W_{fuel}/W_o - fuel fraction	.4760	.4756	.4871

UNCLASSIFIED

(U) Sizing parameters estimation form. (U)

Concept: stealthy

Range = [illegible] nmi
TOGW = [illegible] lb

Mission Segment	Current Technology Baseline M	L/D	SFC	M L/D / SFC	ΔR	ΔWF	4-1 M	L/D	SFC	M L/D / SFC	ΔR	ΔWF	4-3 M	L/D	SFC	M L/D / SFC	ΔR	ΔWF	4-5 M	L/D	SFC	M L/D / SFC	ΔR	ΔWF
WU + TO	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]
CLI + CRUS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.0	0.60	[illegible]	[illegible]	[illegible]	[illegible]	20.0	0.60	[illegible]	[illegible]	[illegible]	[illegible]	16.0	0.60	[illegible]	[illegible]	[illegible]
PEN.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.0	0.82	[illegible]	[illegible]	[illegible]	[illegible]	8.0	0.82	[illegible]	[illegible]	[illegible]	[illegible]	10.0	0.82	[illegible]	[illegible]	[illegible]
WITH.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	0.70	[illegible]	[illegible]	[illegible]	[illegible]	10.0	0.70	[illegible]	[illegible]	[illegible]	[illegible]	12.0	0.70	[illegible]	[illegible]	[illegible]
CLI + CRUS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.0	0.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.60	[illegible]	[illegible]	[illegible]
LOITER	-	[illegible]	[illegible]	[illegible]	-	[illegible]	-	[illegible]	0.65	[illegible]	-	[illegible]	-	[illegible]	0.65	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	-	[illegible]
RES.	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]
Totals					[illegible]	[illegible]					[illegible]	[illegible]					[illegible]	[illegible]					[illegible]	[illegible]
Wfuel Fraction Req'd					[illegible]						[illegible]						[illegible]						[illegible]	

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Category: laser	Concept number	
Parameter	S-1	S-6
Aerodynamics		
L/D MAX for optimum cruise	18	20
L/D at penetration mach number and altitude	10	8
L/D at withdrawal mach number and altitude	10	10
Propulsion		
SFC for optimal cruise	.65	.65
SFC for penetration mach number and altitude	.82	.82
SFC for withdrawal mach number and altitude	.77	.77
SFC for sea-level loiter (≈ 0.3M)	.67	.67
Mass properties		
$W_{empty/Wo}$ = empty weight fraction (estimated)	.31	.31
W_{fix} = weight of fixed equipment items necessary to perform desired task (estimated)	81,376	81,376
Sized vehicle		
W_o = gross weight	420,000	430,000
W_{fuel} = fuel weight	208,620	215,460
$W_{fuel/Wo}$ = fuel fraction	.4967	.5011

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(U) Sizing parameters estimation form. (U)

Concept: laser

Range = 5,250 nmi
TOGW = 395,000 lb

Mission Segment	Current Technology Baseline						S-1						S-6					
	M	L/D	SFC	ML/D SFC	ΔR	ΔWF	M	L/D	SFC	ML/D SFC	ΔR	ΔWF	M	L/D	SFC	ML/D SFC	ΔR	ΔWF
WU + TO	-	-	-	-	-	2,776	-	-	-	-	-	2,776	-	-	-	-	-	2,776
CLI + CRUS	0.72	16.5	0.760	17.526	3,000	101,027	0.72	18.0	0.65	19.938	3,000	88,801	0.72	20.0	0.65	22.154	3,000	79,933
PEN.	0.72	10.1	0.986	8.088	1,000	53,966	0.72	10.0	0.82	8.780	1,000	48,619	0.72	8.0	0.82	7.024	1,000	66,118
WITH.	0.66	11.7	0.897	7.304	750	38,754	0.66	10.0	0.77	7.273	750	38,095	0.66	10.0	0.77	7.273	750	38,691
CLI + CRUS	0.72	16.5	0.760	17.526	500	13,168	0.72	18.0	0.65	19.938	500	11,678	0.72	20.0	0.65	22.154	500	10,417
LOITER	-	18.6	0.767	24.120	-	3,887	-	18.0	0.67	26.866	-	3,580	-	20.0	0.67	29.851	-	3,237
RES.	-	-	-	-	-	8,140	-	-	-	-	-	8,169	-	-	-	-	-	8,169
Totals					5,250	214,846					5,250	196,211					5,250	197,916
Fuel Fraction Req'd.						0.5419						0.4967						0.5011

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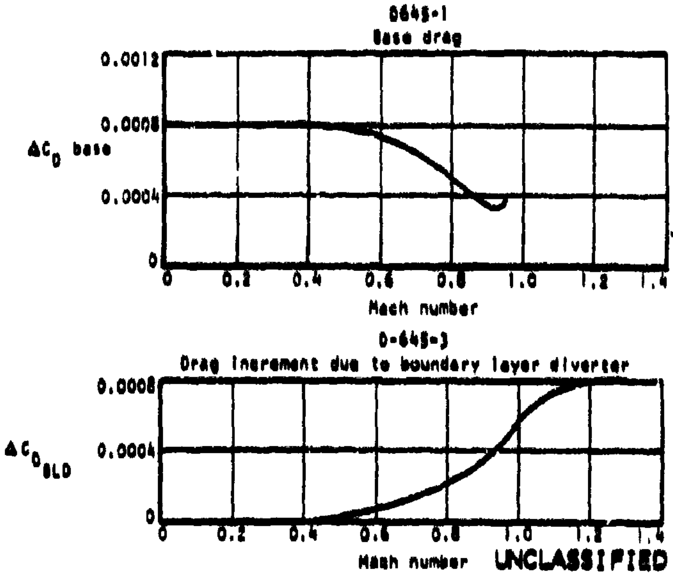
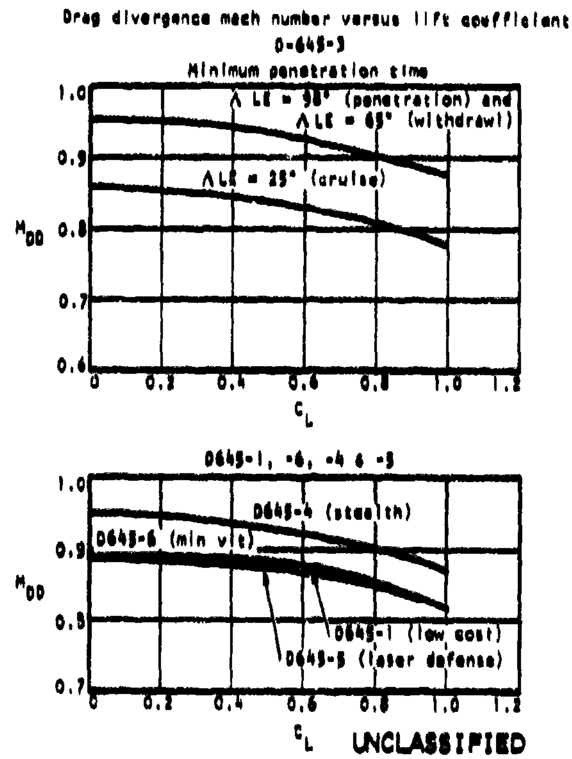
Appendix C

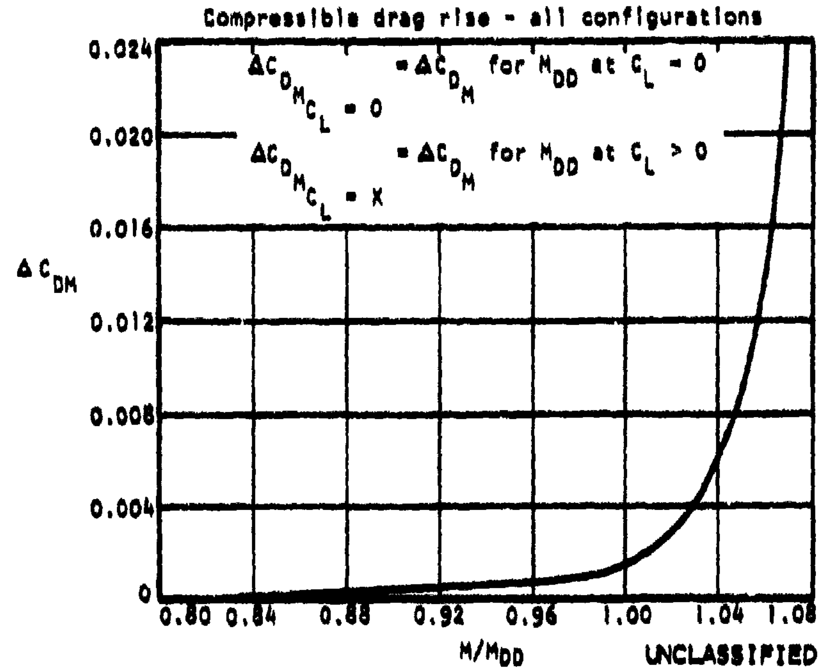
AERODYNAMIC DATA



(U) Figure C-1 (U)

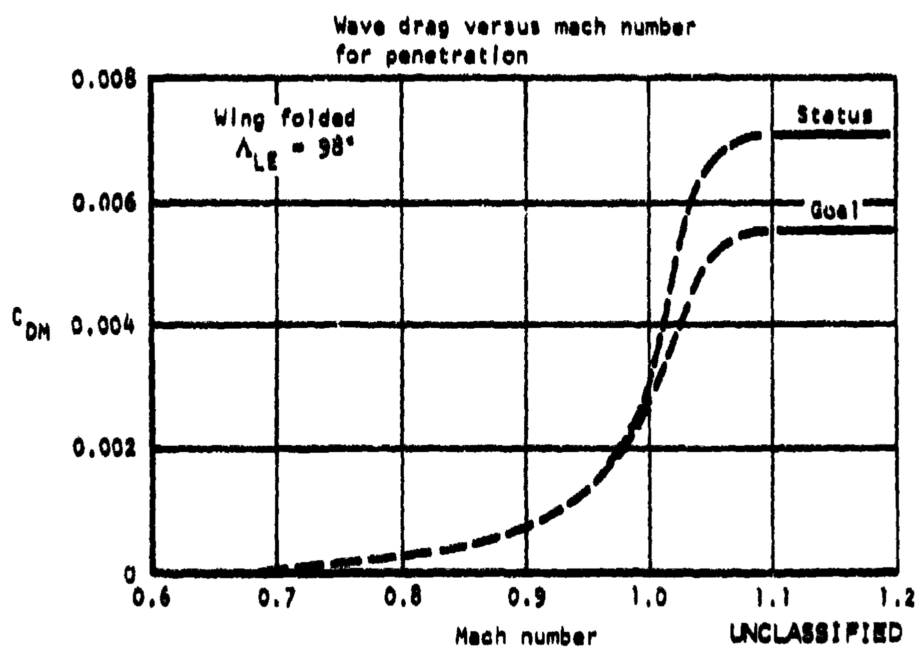


(U) Figure C-2 (U)



(U) Figure C-3 (U)

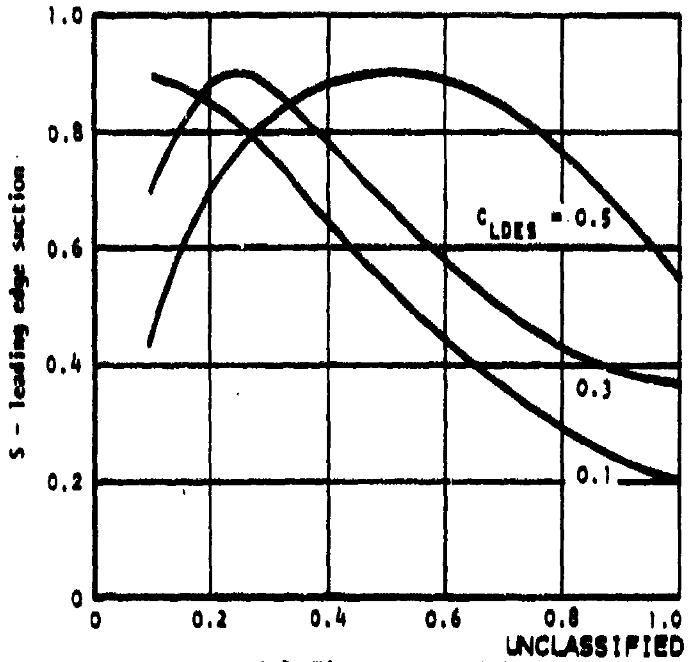
D645-3



(U) Figure C-4 (U)

D-645

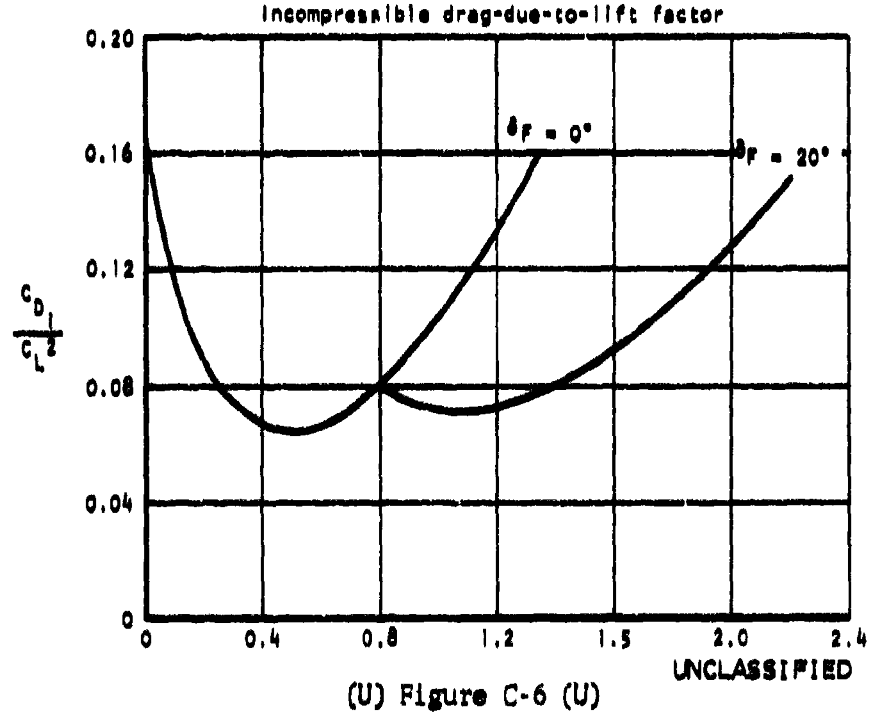
Wing leading edge suction versus lift coefficient



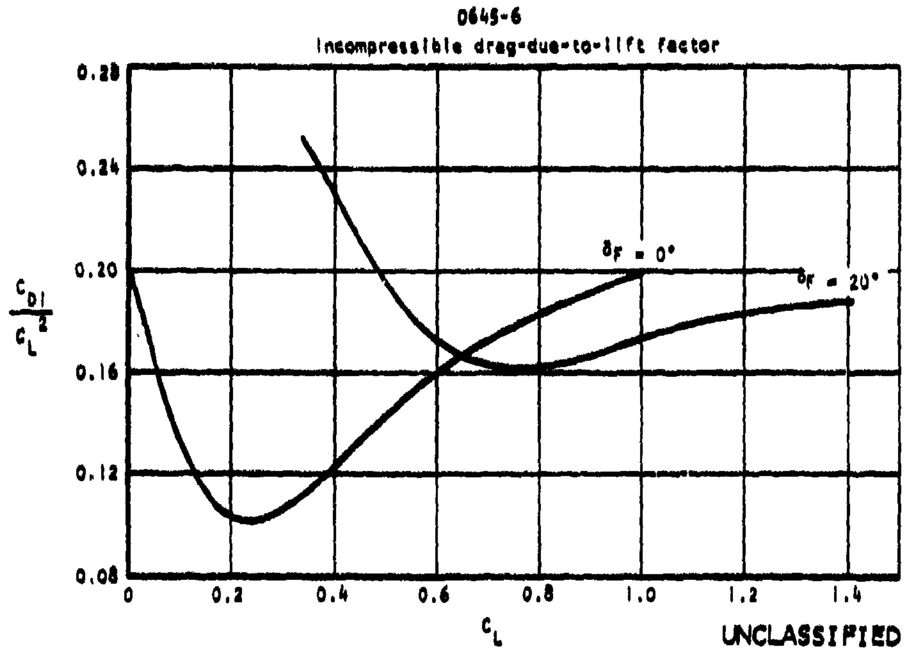
(U) Figure C-5 (U)

D645-1

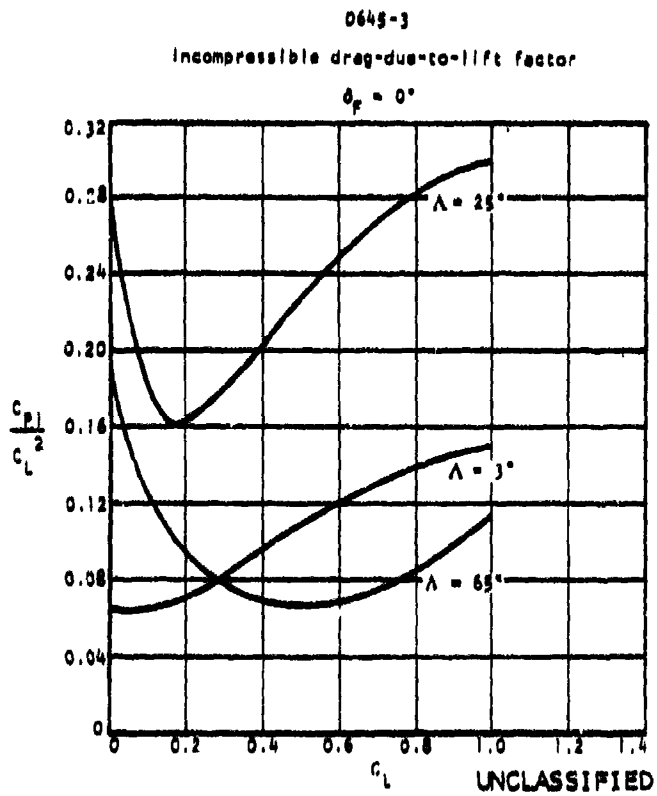
Incompressible drag-due-to-lift factor



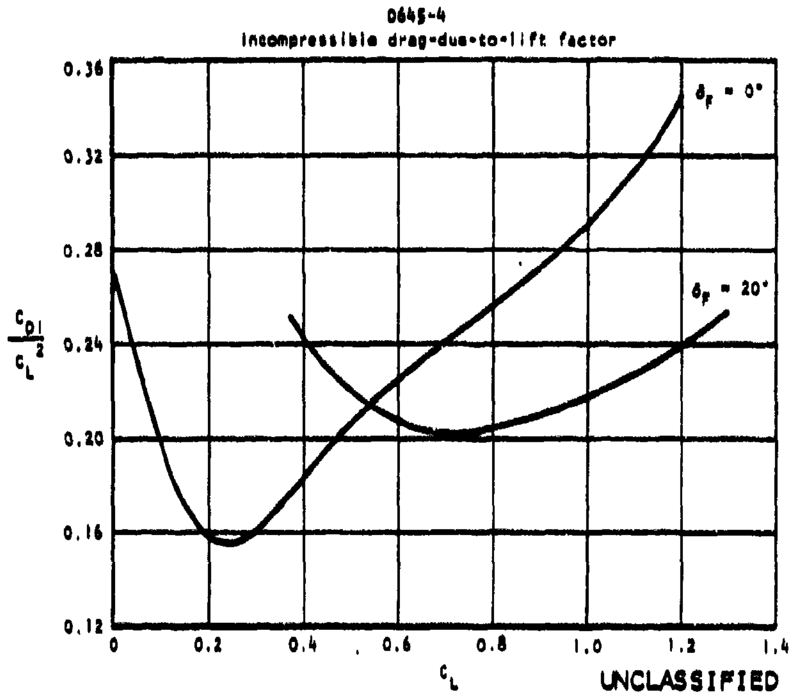
(U) Figure C-6 (U)



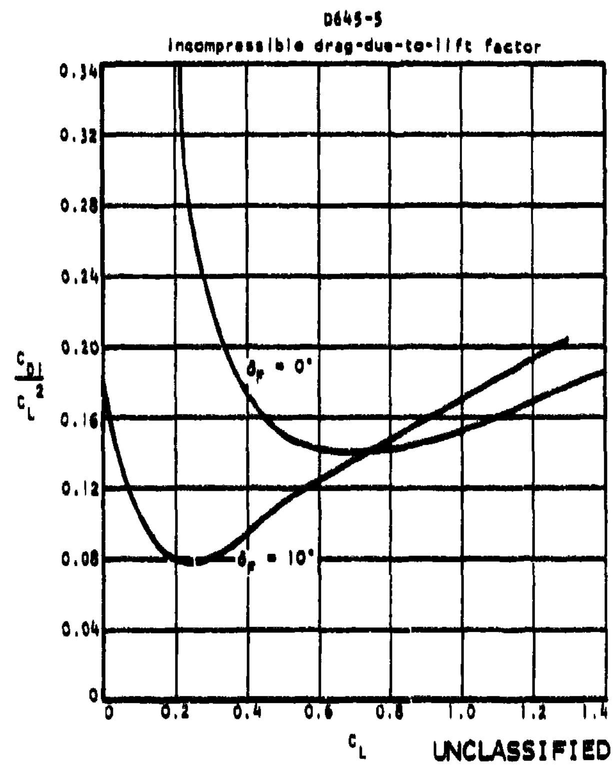
(U) Figure C-7 (U)



(U) Figure C-8 (U)



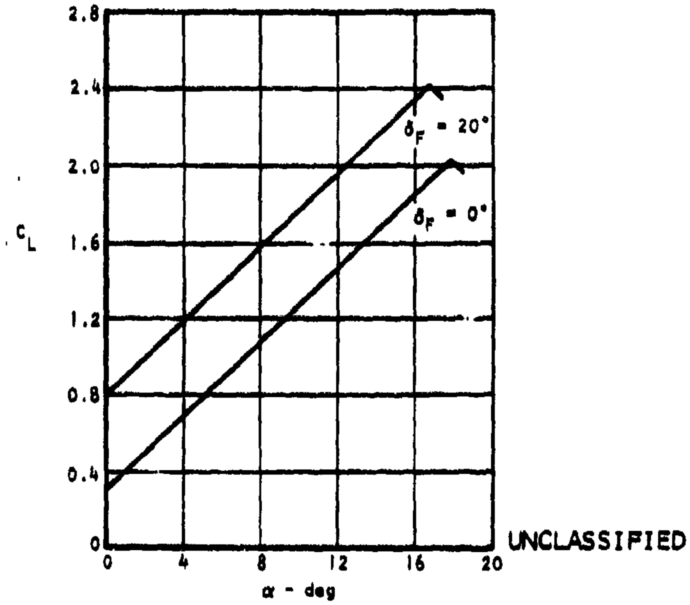
(U) Figure C-9 (U)



(U) Figure C-10 (U)

D645-1

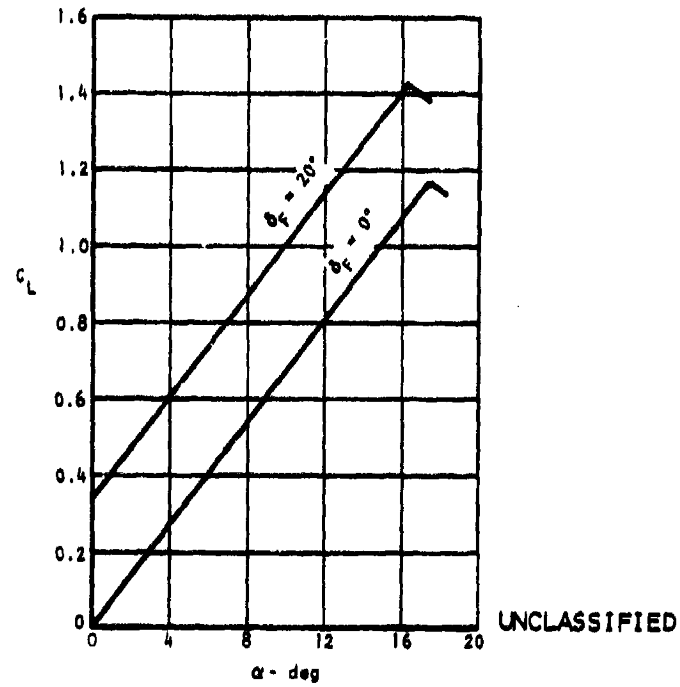
Takeoff and landing lift data



(U) Figure C-11 (U)

D645-6

Takeoff and landing lift data



(U) Figure C-12 (U)

D645-3

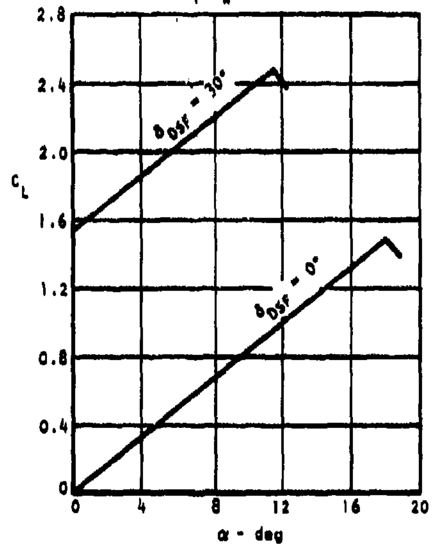
Takeoff and landing lift data

$\lambda_{LE} = 8°$

Double-slotted Flap 30°

$b_f/b_w = 0.785$

$c_f/c_w = 0.25$

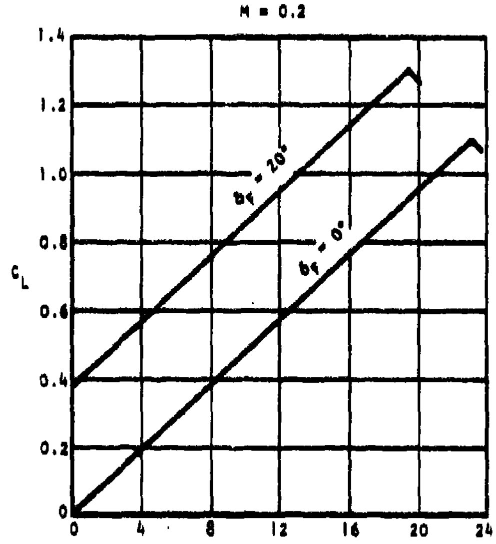


(U) Figure C-13 (U)

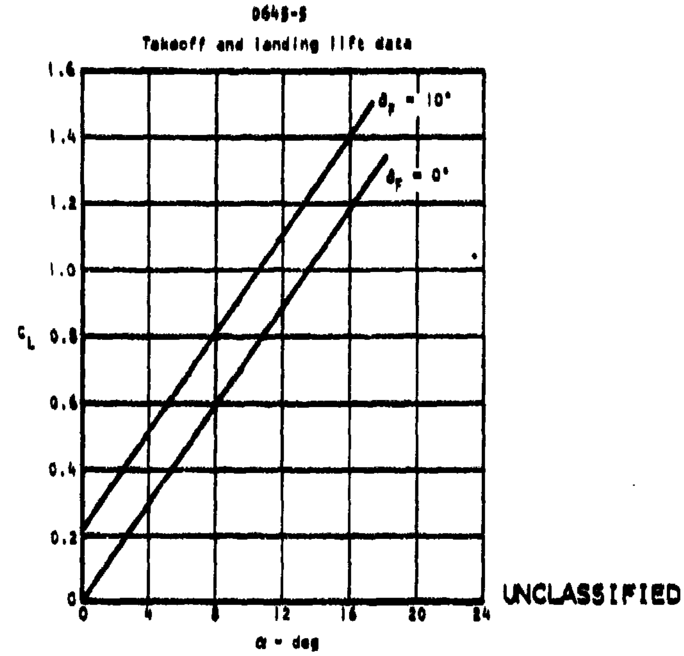
D645-4

Takeoff and landing lift data

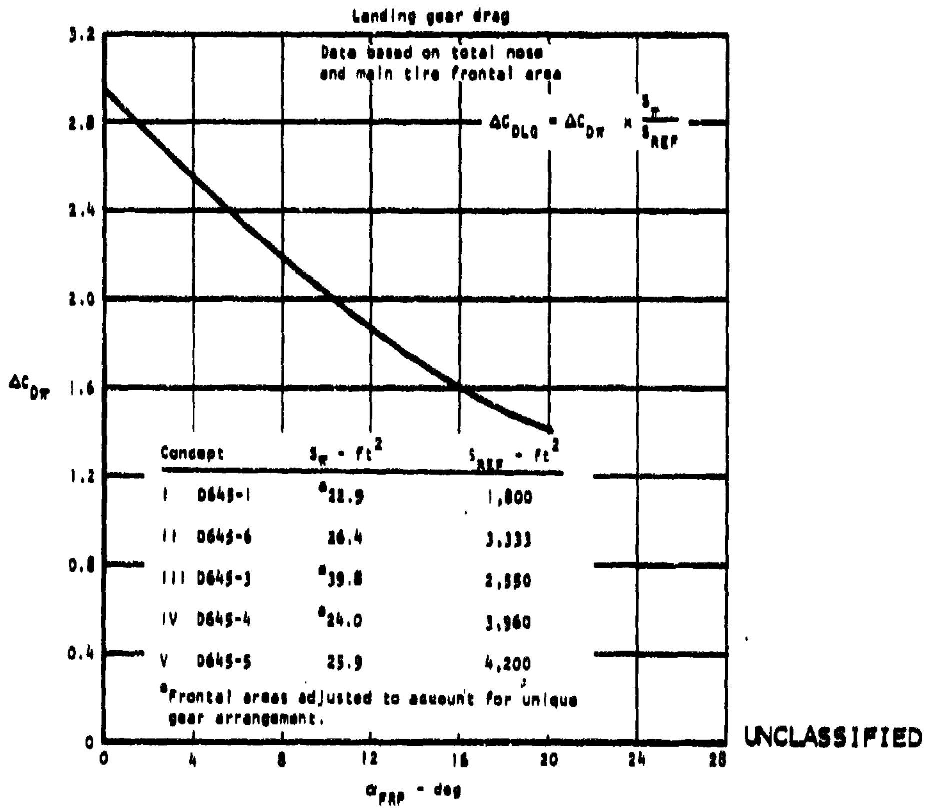
M = 0.2



(U) Figure C-14 (U)



(U) Figure C-15 (U)



Concept	S_π - ft^2	S_{REF} - ft^2
I D645-1	[a]22.9	1,800
II D645-6	26.4	3,333
III D645-3	[a]39.8	2,550
IV D645-4	[a]24.0	3,960
V D645-5	25.9	4,200

[a]Frontal areas adjusted to account for unique gear arrangement.

(U) Figure C-16 (U)

Appendix D

WEIGHTS DATA

(U) TABLE D-1, ISADS - MINIMUM-COST BASELINE - AS DRAWN (U)

WEIGHT SUMMARY

D645-6	Total	Non-DCPR	DCPR
Structure groups	(61,480)	(5,200)	(56,280)
Wing group	15,985		15,985
Tail group - canard	3,730		3,730
- vertical	1,110		1,110
Body group	23,600		23,600
Alighting gear group - main	11,105	4,800	6,305
- auxiliary	1,960		1,500
Engine section or nacelle group	3,990		3,990
Air induction system			
Propulsion group	(12,745)	(9,870)	(2,875)
Engine (as installed)	9,720	9,720	-
Accessory gear boxes and drives	250		250
Exhaust system	-		-
Cooling and drain provisions	20		20
Engine controls	105		105
Starting system	200	150	50
Fuel system	2,450		2,450
Fan (as installed)	-		
Hot gas duct system	-		
Equipment groups	(27,045)	(8,620)	(10,025)
Flight controls group	2,070		2,070
Auxiliary power plant group	300	200	100
Instruments group	855		855
Hydraulic and pneumatic group	780		700
Electrical group	5,240	550	4,690
Avionics group	9,140	6,000	3,080
Armament group	1,105		1,105
Furnishings and equipment group	2,475		2,475
Air conditioning group	4,895	1,810	3,085
Anti-icing group			
Photographic group	-		-
Load and handling group	135		135
Total weight empty	101,870	23,690	78,180
Crew	672		
Fuel - unusable	1,980		
Fuel - usable	198,110		
Oil - engine	180		
Passengers/cargo			
Armament - missile launchers	4,630		
- missiles	80,000		
EXCM dispenser	440		
Equipment - food and water	75		
- survival gear	95		
- miscellaneous	113		
Total useful load	256,207		
Takeoff gross weight	358,107		
Flight design gross weight	300,000		
Landing design gross weight			

(Note: These weights reflect the aircraft as orginally drawn, not the resized aircraft. The final sized weights are given in the test of the report, starting on page)

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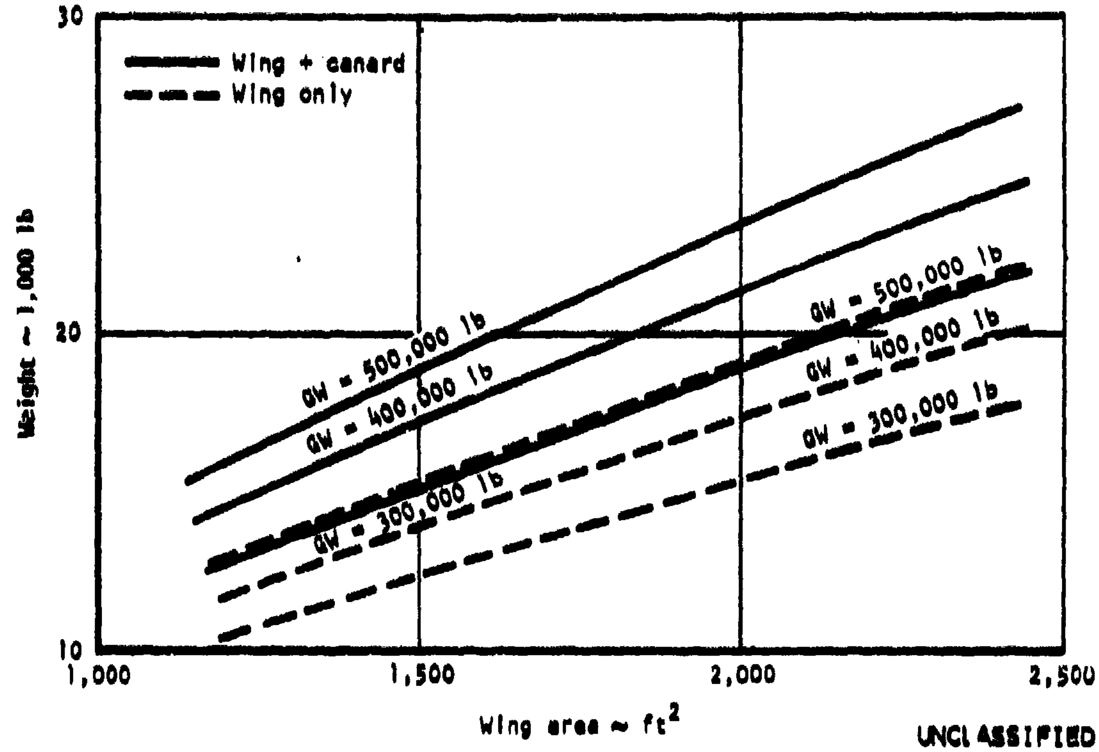

(U) Figure D-1. D645-1 wing-canard weight matrix. (U)

(U) TABLE D-2. D645-1 - ISADS MINIMUM COST BASELINE MATERIAL BREAKDOWN (U)

Component	Total	Non-DCPR	DCPR	Aluminum	Titanium	Steel	Advanced composite	Resonant Array (Fiber-glass/metal)	Misc and others
Wing	(51,988)		(15,985)		(630)	(40)	(14,475)	(360)	(480)
Multispar/plate	14,115		14,115		155	40	13,455		465
SPF/DB	490		400		475				15
Bonded honeycomb	1,380		1,380				1,020	360	
Canard	(3,730)		(3,730)		(235)	(10)	(3,240)	(135)	(110)
Multispar/plate	3,090		3,090		40	10	2,935		105
SDF/DB	200		200		195				5
Bonded honeycomb	440		440				305	135	
Vertical	(1,110)		(1,110)		(90)		(925)	(60)	(35)
Multispar/plate	760		760		5		720		35
SPF/DB	85		85		85				
Bonded honeycomb	265		265				205	60	
Fuselage	(23,600)		(23,600)	(18,985)	(1,300)	(150)	(1,700)	(455)	(1,010)
Frame/longeron - SPF	21,740		21,740	18,985	1,300	150		295	1,010
Bonded honeycomb	1,860		1,860				1,700	160	
Main gear	11,105	4,800	6,305	935	370	4,885			115
Nose gear	1,960	400	1,560	385	85	1,065			25
Nacelle und eng sect	(3,990)		(3,990)		(2,780)	(400)	(690)		(120)
Frame/longeron	1,890		1,890		745	400	690		55
SPF/DB	2,100		2,100		2,035				65
Total structure	61,480	5,200	56,280	20,305	5,490	6,550	21,030	1,010	1,898

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(U) TABLE D-3. ISADS MINIMUM WEIGHT BASELINE - AS DRAWN (U)

WEIGHT SUMMARY

D645-6	Total	Non-DCPR	DCPR
Structure groups	(50,870)	(4,550)	(46,320)
Wing group	28,700		28,780
Tail group - canard	1,330		1,330
- vertical	1,250		1,250
Body group	6,060		6,060
Alighting gear group - main	8,300	4,200	4,180
- auxiliary	1,480	350	1,130
Engine section or nacelle group	3,590		3,500
Air induction system			
Propulsion group	(12,400)	(9,870)	(2,530)
Engine (as installed)	9,720	9,720	-
Accessory gear boxes and drives	250		250
Exhaust system	-		-
Cooling and drain provisions	20		20
Engine controls	105		105
Starting system	200	150	50
Fuel system	2,105		2,108
Fan (as installed)	-		
Hot gas duct system	-		
Equipment groups	(26,890)	(8,578)	18,315
Flight controls group	2,375		2,375
Auxiliary power plant group	330	200	130
Instruments group	855		855
Hydraulic and pneumatic group	740		740
Electrical group	4,820	505	1,315
Avionics group	9,140	6,060	3,080
Armament group	1,165		1,168
Furnishings and equipment group	2,478		2,475
Air conditioning group	4,895	1,810	3,085
Anti-icing group			
Photographic group	-		-
Load and handling group	125		125
Total weight empty	90,160	22,995	67,165
Crew	673		
Fuel - unusable	1,080		
Fuel - usable	108,000		
Oil - engine	180		
Passengers/cargo			
Armament - missile launchers	4,630		
- missiles	80,000		
EXCM dispenser	440		
Equipment - food and water	73		
- survival gear	95		
- miscellaneous	113		
Total useful load	225,887		
Takeoff gross weight	316,047		
Flight design gross weight	380,000		
Landing design gross weight			

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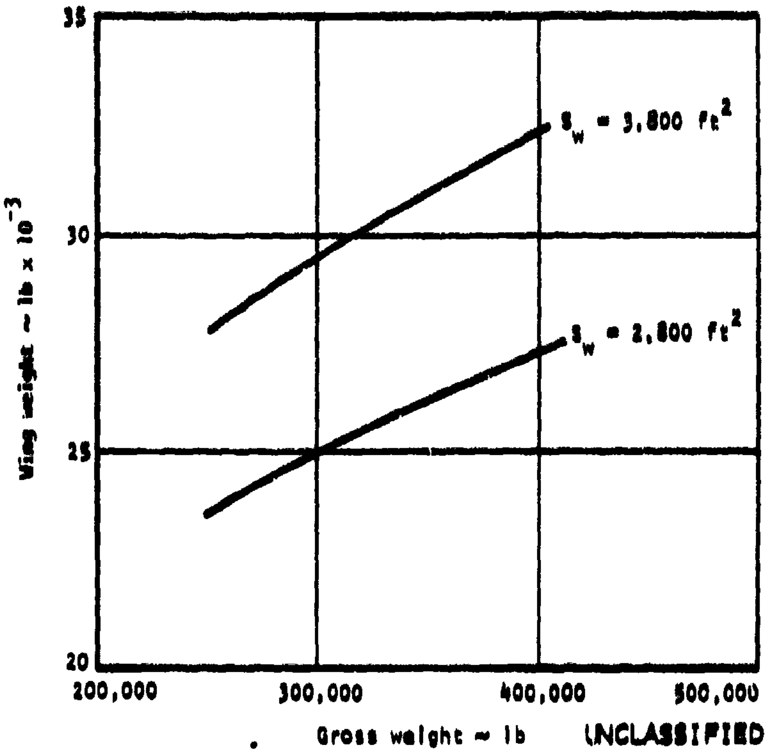

(U) Figure D-2. D645-6 ISADS spanloader wing weight matrix. (U)

(U) TABLE D-4. D645-6 - ISADS MINIMUM WEIGHT SPANLOADER CONCEPT MATERIAL BREAKDOWN (U)

Component	Total	Non-DCPR	DCPR	Aluminum	Titanium	Steel	Advanced composite	Resonant array (fiberglass/metal)	Misc and others
Wing	(28,780)		(28,780)		(2,035)	(180)	(25,145)	(770)	(680)
Multispar plate	22,105		22,105		1,600	180	19,690		665
SPF/DB	450		450		435				15
Bonded honeycomb	6,225		6,225				5,455	770	
Canard	(1,330)		(1,330)		(80)	(40)	(1,170)		(40)
SPF/DB	80		80		80				
Bonded honeycomb	1,250		1,250			40	1,170		40
Vertical	(1,250)		(1,250)		(140)		(1,075)		(35)
Multispar plate	710		710		5		670		35
SPF/DB	135		135		135				
Bonded honeycomb	405		405				405		
Fuselage	(6,060)		(6,060)	(4,670)			(675)	(170)	(545)
Frame/longeron - SPF	5,890		5,890	4,670			675		545
Bonded honeycomb	170		170					170	
Main gear	8,380	4,200	4,180	605	245	7,455			75
Nose gear	1,480	330	1,150	275	65	1,125			15
Nacelle and eng sect	(3,590)		(3,590)		(2,500)	(360)	(620)		(110)
Frame/longeron	1,700		1,700		665	360	620		55
SPF/DB	1,890		1,890		1,835				55
Total structure	(50,870)	(4,530)	(46,320)	(5,550)	(5,065)	(4,880)	(28,085)	(940)	(1,500)

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(U) TABLE D-5. ISADS MINIMUM PENETRATION TIME BASELINE - AS DRAWN (U)

WEIGHT SUMMARY

D645-6	Total	Non-DCPR	DCPR
Structure groups	(106,740)	(6,630)	(100,110)
Wing group	29,810		29,810
Tail group - canard	800		800
- vertical	1,005		1,005
Body group	57,270		57,270
Alighting gear group - main	6,925	3,315	3,610
- auxiliary	6,925	3,315	3,010
Engine section or nacelle group	525		525
Air induction system	3,420		3,420
Propulsion group	(32,720)	(28,090)	(4,630)
Engine (as installed)	27,880	27,880	-
Accessory gear boxes and drives	400		400
Exhaust system	-		-
Cooling and drain provisions	40		40
Engine controls	215		215
Starting system	285	210	75
Fuel system	3,900		3,900
Fan (as installed)	-		
Hot gas duct system	-		
Equipment groups	(27,905)	(6,805)	(21,010)
Flight controls group	5,045		5,045
Auxiliary power plant group	300	200	100
Instruments group	955		955
Hydraulic and pneumatic group	1,175		1,175
Electrical group	5,550	580	4,970
Avionics group	6,085	4,190	1,895
Armament group	1,105		1,105
Furnishings and equipment group	2,305		2,305
Air conditioning group	5,200	1,925	3,275
Anti-icing group			
Photographic group	-		
Load and handling group	125		125
Total weight empty	167,365	41,615	125,750
Crew	448		
Fuel - unusable	3,250		
Fuel - usable	325,000		
Oil - engine	300		
Passengers/cargo			
Armament - missile launchers	4,630		
- missiles	50,000		
EXCM dispenser	440		
Equipment - food and water	30		
- survival gear	65		
- miscellaneous	115		
Total useful load	384,358		
Takeoff gross weight	551,723		
Flight design gross weight	510,000		
Landing design gross weight			

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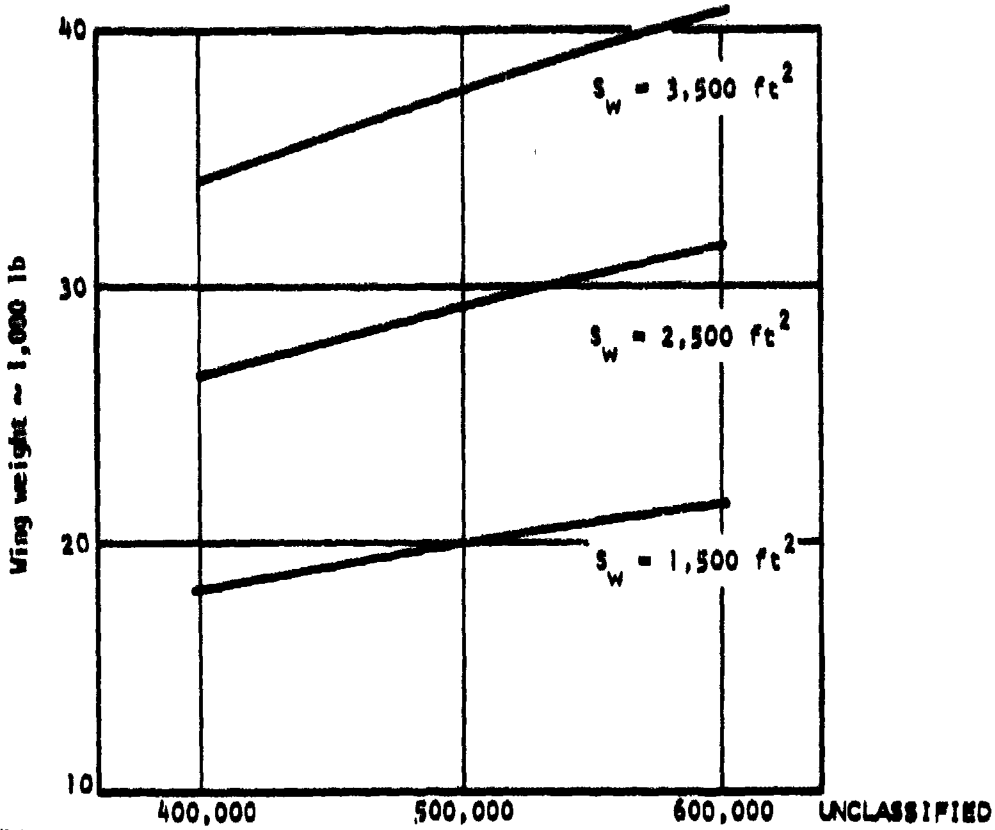

(U) Figure D-3. D645-3 ISADS minimum penetration time baseline wing weight matrix. (U)

(U) TABLE D-6. D645-3 - ISADS MINIMUM PENETRATION TIME BASELINE MATERIAL BREAKDOWN (U)

Component	Total	Non-DCPR	DCPR	Aluminum	Titanium	Steel	Advanced composite	Resonant array (fiberglass/metal)	Misc and others
Wing	(29,810)		(29,810)		(8,300)	(200)	(20,190)		(830)
Multispar plate	18,815		18,815			200	18,050		565
SPF/DB	8,855		8,855		8,590				265
Bonded honeycomb	2,140		2,140				2,140		
Canard	(860)		(860)		(55)	(25)	(755)		(25)
SPF/DB	55		55		55				
Bonded honeycomb	805		805			25	755		25
Vertical	(1,005)		(1,005		(85)		(890)		(30)
Multispar plate	600		600		5		565		30
SPF/DB	80		80		80				
Bonded honeycomb	325		318				325		
Fuselage	(57,270)		(57,270)	(38,455)	(7,065)	(200)	(9,185)	(345)	(2,020)
Frame/longeron + SPF	55,050		55,050	38,455	7,065	200	6,965	345	2,020
Bonded honeycomb	2,220		2,220				2,220		
Main gear (fwd)	6,925	3,315	3,610	835	210	2,500			65
Main gear (aft)	6,925	3,315	3,610	835	210	2,500			65
Eng sect and AIS	(3,945)		(3,945)		(485)	(400)	(2,945)		(115)
Frame/longeron	3,300		3,300			400	2,800		100
SPF/DB	500		500		485				15
Bonded honeycomb	145		145				145		
Total structure	(106,740)	(6,630)	(100,100)	(39,125)	(16,700)	(6,125)	(33,065)	(345)	(3,130)

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(U) TABLE D-7. ISADS STEALTH BASELINE - AS DRAWN (U)

WEIGHT SUMMARY

D645-6	Total	Non-DCPR	DCPR
Structure groups	(49,350)	(5,355)	(43,995)
Wing group	32,980		32,980
Tail group - canard			
- vertical	650		650
Body group			
Alighting gear group - main	11,120	4,948	6,173
- auxiliary	1,960	410	1,550
Engine section or nacelle group	225		225
Air induction system	2,445		2,445
Propulsion group	(14,115)	(11,410)	(2,705)
Engine (as installed)	11,260	11,260	-
Accessory gear boxes and drives	250		250
Exhaust system	-	-	-
Cooling and drain provisions	20		20
Engine controls	105		105
Starting system	200	150	50
Fuel system	2,280		2,280
Fan (as installed)	-		
Hot gas duct system	-		
Equipment groups	(26,980)	(8,560)	(18,300)
Flight controls group	2,525		2,525
Auxiliary power plant group	300	200	100
Instruments group	855		855
Hydraulic and pneumatic group	785		785
Electrical group	4,505	400	4,105
Avionics group	9,140	6,060	3,080
Armament group	1,165		1,165
Furnishings and equipment group	2,475		2,475
Air conditioning group	4,895	1,810	3,085
Anti-icing group			
Photographic group	-		
Load and handling group	125		125
Total weight empty	90,415	25,325	65,090
Crew	673		
Fuel - unusable	1,830		
Fuel - usable	183,000		
Oil - engine	180		
Passengers/cargo			
Armament - missile launchers	4,630		
- missiles	50,000		
ECM dispenser	440		
Equipment - food and water	75		
- survival gear	95		
- miscellaneous	115		
Total useful load	241,037		
Takeoff gross weight	331,452		
Flight design gross weight	412,000		
Landing design gross weight			

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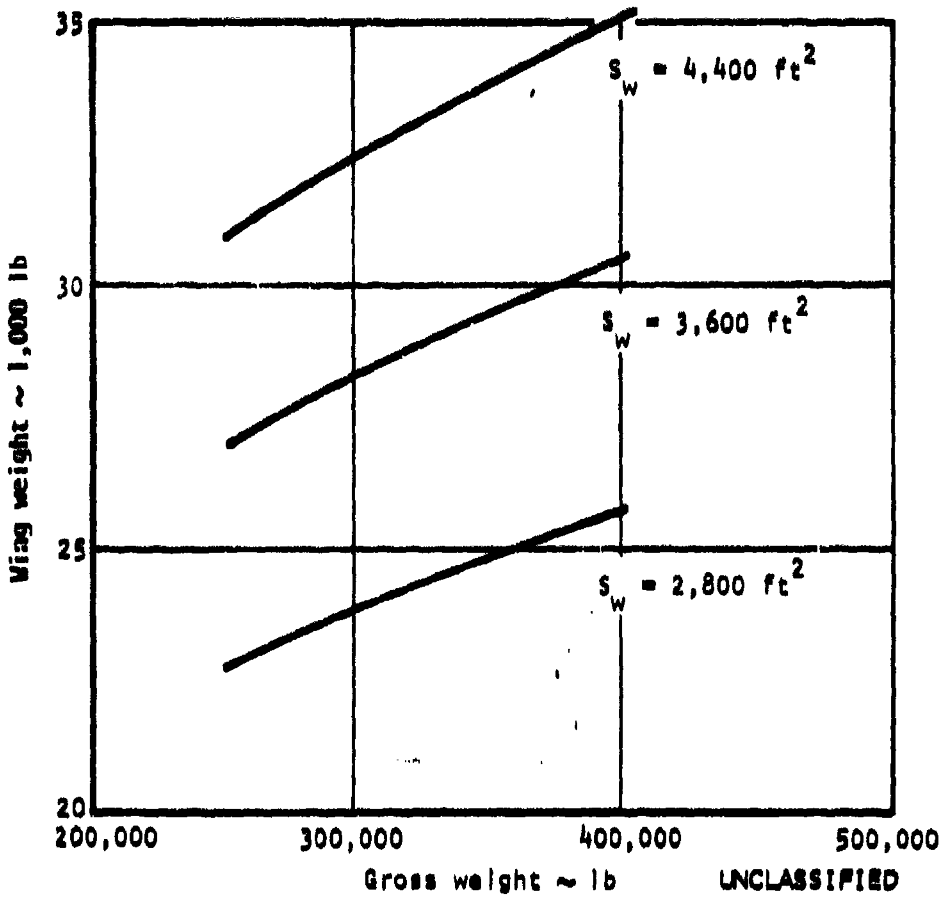

(U) Figure D-4. D645-4 ISADS stealth baseline wing weight matrix. (U)

(U) TABLE D-8. D645-4 - ISADS STEALTH BASELINE MATERIAL BREAKDOWN (U)

Component	Total	Non-DCPR	DCPR	Aluminum	Titanium	Steel	Advanced composite	Resonant array (fiberglass/metal)	Misc and others
Wing	(32,050)		(32,050)	(1,600)	(3,175)	(310)	(25,690)	(940)	(1,235)
Multispar plate	27,485		27,485	1,600	1,850	310	22,530		1,195
SPF/DB	1,365		1,365		1,325				40
Bonded honeycomb	4,100		4,100				3,160	940	
Vertical	(650)		(650)		(75)		(555)		(20)
Multispar plate	375		375		10		345		20
SPF/DB	65		65		65				
Bonded honeycomb	210		210				210		
Main gear	11,120	4,945	6,175	915	365	4,785			110
Nose gear	1,960	410	1,550	385	85	1,060			20
Fug sect and AIS	(2,670)		(2,670)		(115)	(160)	(2,315)		(80)
Frame/longeron	2,550		2,550			160	2,315		75
SPF/DB	120		120		115				5
Total structure	(49,350)	(5,355)	(43,995)	(2,900)	(3,815)	(6,315)	(28,560)	(940)	(1,465)

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(U) TABLE D-9. ISADS DEFENSIVE LASER BASELINE - AS DRAWN (U)

WEIGHT SUMMARY

D645-5	Total	Non-DCPR	DCPR
Structure groups	(59,210)	(5,455)	(53,755)
Wing group	26,810		26,810
Tail group - canard	320		320
- vertical	1,020		1,020
Body group	12,355		12,355
Alighting gear group - main	10,205	5,040	5,165
- auxiliary	1,800	415	1,385
Engine section or nacelle group	5,800		5,800
Air induction system			
Propulsion group	(16,695)	(11,630)	(5,065)
Engine (as installed)			
F_N (SLS) = 27,500 #/Engine	11,420	11,420	-
Accessory gear boxes & drives	400		400
Exhaust system	-		-
Cooling & drain provisions	40		40
Engine controls	215		215
Starting system	285	210	75
Fuel system	4,335		4,335
Fan (as installed)	-		
Hot gas duct system	-		
Equipment groups	(33,460)	(11,730)	(21,730)
Flight controls group	2,790		2,790
Auxiliary power plant group	300	200	100
Instruments group	955		955
Hydraulic and pneumatic group	1,260		1,260
Electrical group	6,295	600	5,635
Avionics group	12,935	8,980	3,955
Armament group	1,165		1,165
Furnishings and equipment group	2,530		2,530
Air conditioning group	5,105	1,890	3,215
Anti-icing group			
Photographic group	-		
Load and handling group	125		125
HELWS (dry)	10,360		10,360
Total weight empty	119,725	28,815	90,910
Crew	672		
Fuel - unusable	3,440		
Fuel - usable	344,000		
Oil - engine	240		
Passengers/cargo			
Armament - missile launchers	4,630		
- missiles	50,000		
EXCM dispenser	440		
HELWS fuel	2,065		
Equipment - food and water	75		
- survival gear	95		
- miscellaneous	115		
Total useful load	406,672		
Takeoff gross weight	526,397		
Flight design gross weight	420,000		
Landing design gross weight			

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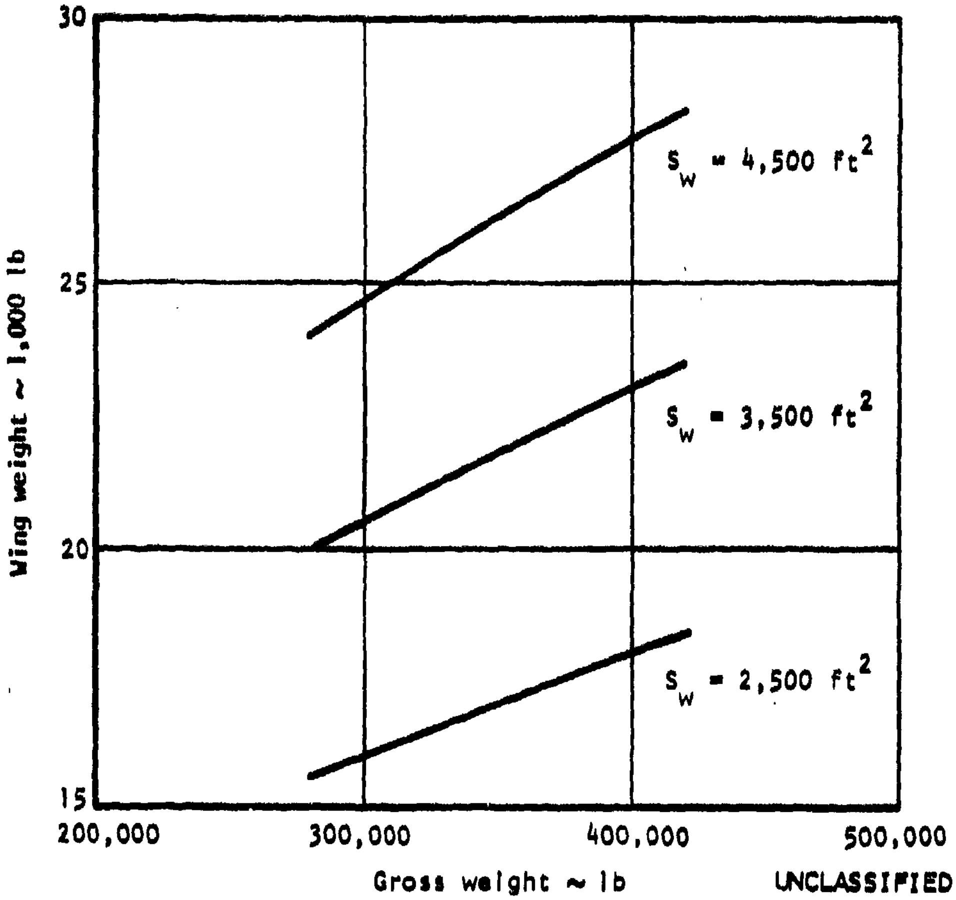

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(U) Figure D-5. D645-5 ISADS - defensive laser concept wing weight matrix. (U)

(U) TABLE D-10. D645-5 - ISADS DEFENSIVE LASER CONCEPT MATERIAL BREAKDOWN (U)

Component	Total	Non-DCPR	DCPR	Aluminum	Titanium	Steel	Advanced composite	Resonant array (fiberglass/metal)	Misc and others
Wing	(26,810)		(26,810)		(2,230)	(440)	(22,625)	(840)	(675)
Multispare plate	21,765		21,765		1,650	440	19,015		660
SPF/DB	595		595		580				15
Bonded honeycomb	4,450		4,450				3,610	840	
Vertical and ventral	(2,240)		(2,240)		(370)		(1,805)		(65)
Multispar plate	1,265		1,265		10		1,190		65
SPF/DB	360		360		360				
Bonded honeycomb	615		615				615		
Fuselage	(12,355)		(12,355)	(7,630)	(1,000)	(150)	(2,785)	(100)	(690)
Frame/longeron - SPF	10,725		10,725	7,630	1,000	150	1,255		690
Bonded honeycomb	1,630		1,630				1,530	100	
Main gear	10,205	5,040	5,165	765	300	4,005			95
Nose gear	1,800	415	1,385	340	75	950			20
Nacelle and eng sect	(5,800)		(5,800)		(4,510)	(160)	(955)		(175)
Frame/longeron	1,150		1,150			160	955		35
SPF/DB	4,650		4,650		4,510				140
Total structure	(59,210)	(5,455)	(53,755)	(8,735)	(8,485)	(5,705)	(28,170)	(940)	(1,720)

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Appendix E

PROPULSION DATA

SUBSONIC ENGINE CHARACTERISTICS

(U) TABLE B-1. MF78-01 COMPONENT PERFORMANCE LEVELS (U)

Fan	
Design pressure ratio	3.7
Number of stages	3
Design adiabatic efficiency	0.844
Design inlet mach number	0.55
Design outlet mach number	0.5
Hub/tip ratio	0.39
Bypass duct mach number	0.3
Compressor	
Design corrected flow ($W\sqrt{\theta_{T2}}/\delta_{T2}$), lb/sec	68.4
Design pressure ratio	9.5
Number of stages	7
Design adiabatic efficiency	0.87
Design inlet mach number	0.5
Design outlet mach number	0.35
Hub/tip ratio	0.8
Maximum discharge pressure limit, psia	700
Combustor	
Design efficiency	0.99
Design pressure loss, $\Delta P/P$	0.06
Design diffuser inlet mach number	0.3
Fuel lower heating value, BTU/lb	18,560

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TABLE E-1. MF78-01 COMPONENT PERFORMANCE LEVELS (CONCL) (U)

High-pressure turbine	
Design adiabatic efficiency	0.895
Stator cooling flow, % of compressor flow	3
Rotor cooling flow, % of compressor flow	3
Design discharge mach number	0.45
Number of stages	1
Low-pressure turbine	
Design adiabatic efficiency	0.91
Stator cooling flow	0
Rotor cooling flow	0
Design discharge mach number	0.45
Number of stages	2
Augmenter	
Design efficiency	0.95
Design total pressure loss, ΔP/P	0.15
Dry total pressure loss, ΔP/P	0.045
Maximum augmenter temperature, °R	3,960
Inlet mach number	0.25
Mixer	
Hot-stream mach number	0.3
Cold-stream mach number	0.3
Mixed-stream mach number	0.3
Hot-stream pressure loss, ΔP/P	0.015
Cold-stream pressure loss (fan to mixer, ΔP/P	0.025
Mixing pressure loss, ΔP/P	0.02

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(U) TABLE E-2. MF78-01 INSTALLATION EFFECTS (U)

Inlet type	Pitot
Capture area, sq in.	2,013
Throat area, sq in.	1,610
Throat/capture area	0.8
Subsonic duct loss coefficient	0.03
Inlet recovery	Theoretical computer program
Inlet drag	Figure E-1
Nozzle external performance	Figure E-2
Gross thrust loss due to leakage and friction	0.015
Gross thrust loss due to under/overexpansion	Theoretical computer program
Power extraction, hp	400
Compressor interstage bleed, lb/sec	2.0

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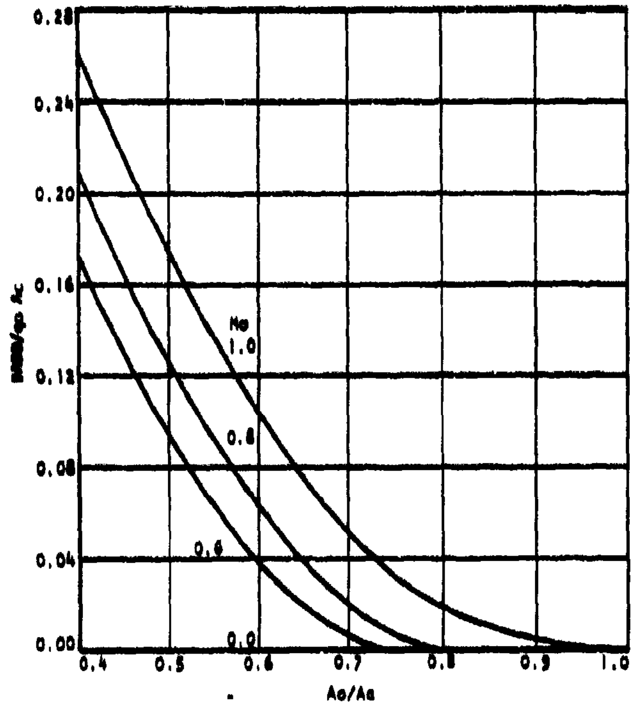

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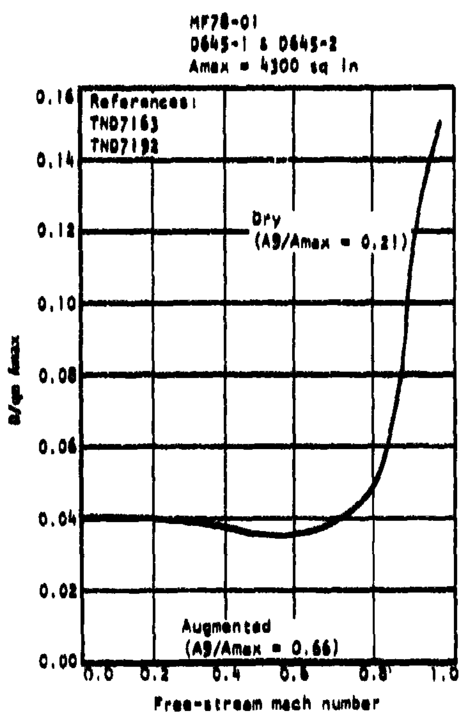
(U) Figure E-1. Pitot inlet drag, low-cost aircraft. (U)



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(U) Figure E-2. Nozzle/afterbody drag increment, low-cost aircraft. (U)

SUPERSONIC ENGINE CHARACTERISTICS

(U) TABLE B-3. MF78-02 COMPONENT PERFORMANCE LEVELS (U)

Fan	
Design pressure ratio	3.4
Number of stages	3
Design adiabatic efficiency	0.855
Design inlet mach number	0.55
Design outlet mach number	0.5
Hub/tip ratio	0.39
Bypass duct mach number	0.3
Compressor	
Design corrected flow ($W\sqrt{\theta}_{T2}/\delta_{T2}$), lb/sec	65.2
Design pressure ratio	10.3
Number of stages	7
Design adiabatic efficiency	0.87
Design inlet mach number	0.5
Design outlet mach number	0.35
Hub/tip ratio	0.8
Maximum discharge pressure limit, psia	810
Combustor	
Design efficiency	0.99
Design pressure loss, $\Delta P/P$	0.06
Design diffuser inlet mach number	0.3
Fuel lower heating value, BTU/lb	18,560

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TABLE B-3. MF78-02 COMPONENT PERFORMANCE LEVELS (CONCL) (U)

High-pressure turbine	
Design adiabatic efficiency	0.895
Stator cooling flow, % of compressor flow	3.6
Rotor cooling flow, % of compressor flow	3.6
Design discharge mach number	0.45
Number of stages	2
Low-pressure turbine	
Design adiabatic efficiency	0.91
Stator cooling flow	0
Rotor cooling flow	0
Design discharge mach number	0.45
Number of stages	2
Augmenter	
Design efficiency	0.95
Design total pressure loss, ΔP/P	0.164
Dry total pressure loss, ΔP/P	0.045
Maximum augmenter temperature, °R	3,960
Inlet mach number	0.27
Mixer	
Hot-stream mach number	0.31
Cold-stream mach number	0.31
Mixed-stream mach number	0.31
Hot-stream pressure loss, ΔP/P	0.015
Cold-stream pressure loss (fan to mixer), ΔP/P	0.025
Mixing pressure loss, ΔP/P	0.02

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(U) TABLE E-4. MF78-01 INSTALLATION EFFECTS (U)

Inlet type	Pitot
Capture area, sq in.	1,768
Auxiliary inlet area, sq in.	860
Inlet recovery	Figure E-3
Inlet drag	Figure E-4
Nozzle performance	Figure E-5
Gross thrust loss due to leakage	0.005
Power extraction, hp	250
Compressor interstage bleed, lb/sec	1.3

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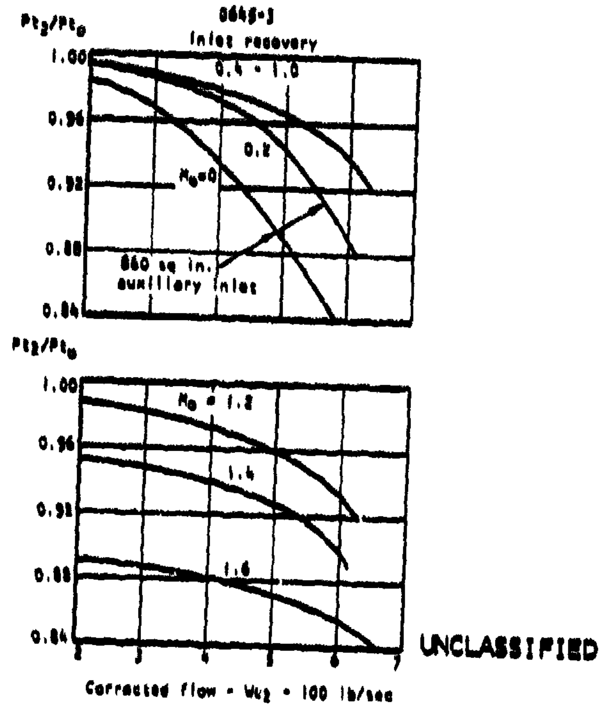
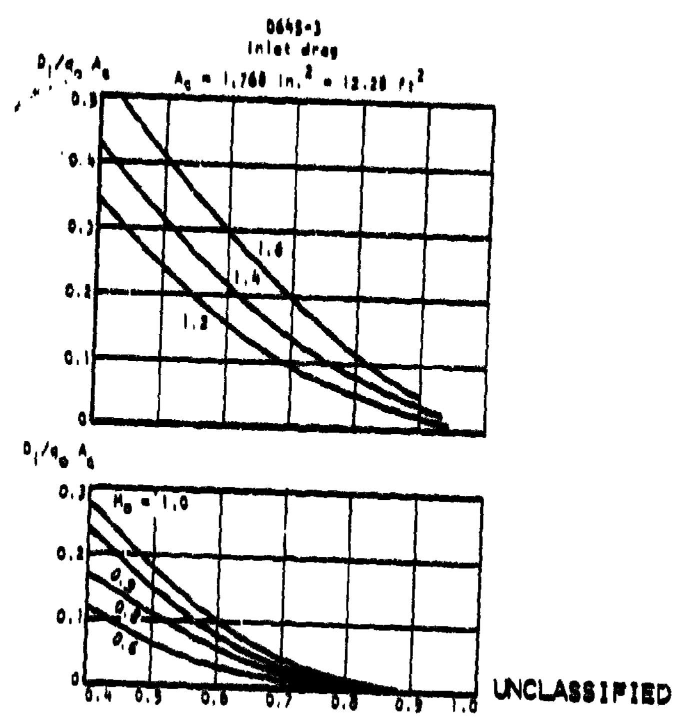
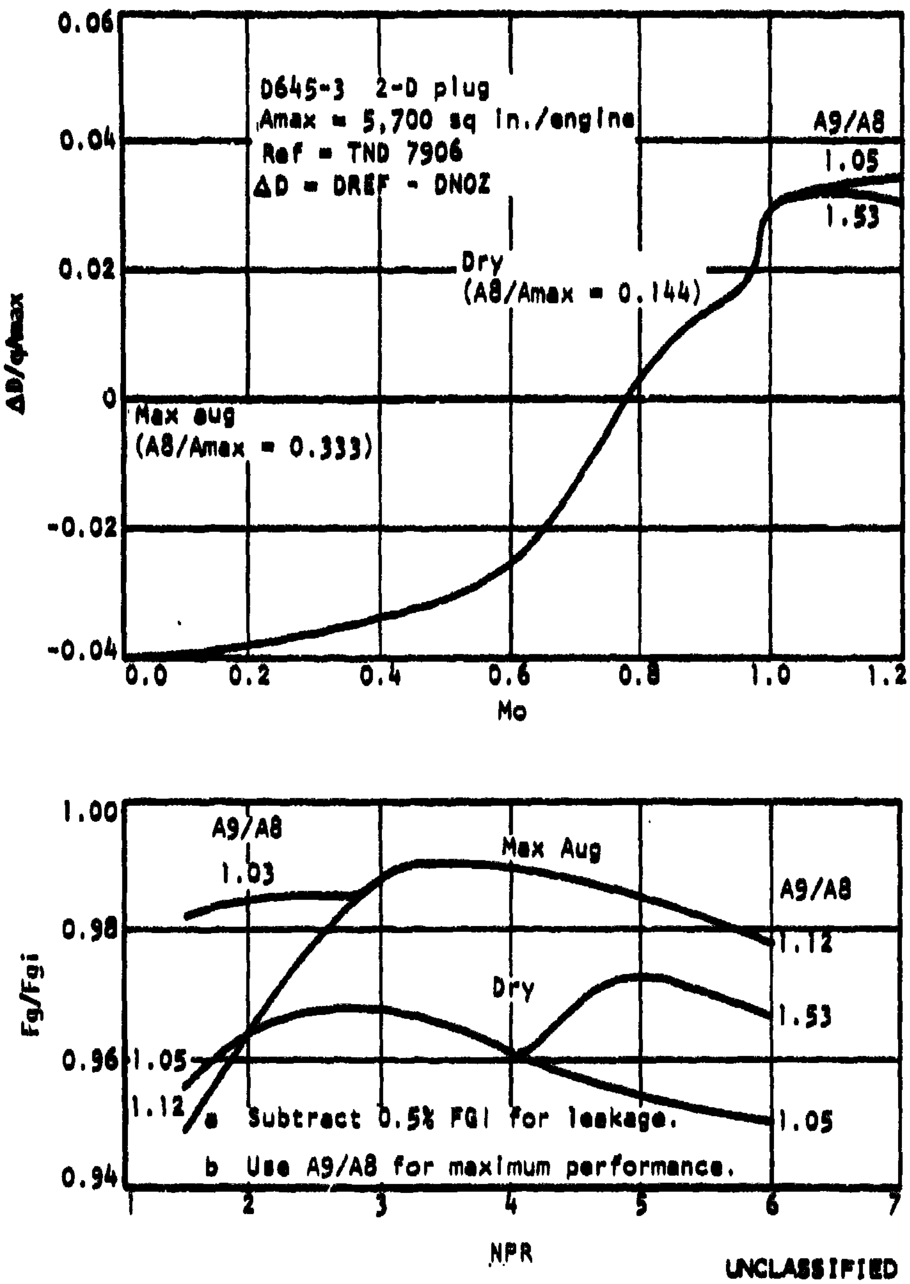


(U) Figure B-3. Inlet recovery, minimum time penetrator. (U)



(U) Figure B-4. Inlet drag, minimum time penetrator. (U)



(U) Figure E-5. Nozzle performance, minimum time penetrator. (U)

NUCLEAR ENGINE CHARACTERISTICS

NUCLEAR POWER

(U) A trade study was performed to determine if nuclear reactors could be used to power aircraft engines and be competitive with conventionally powered aircraft. It appears that with a vigorous research and development program, the necessary technology could be made available for a strategic aircraft with an IOC in the year 2000.

(U) It was found in previous studies (References 17 and 18) that use of JP fuel for an emergency range capability and for takeoff and landing (with the reactor inoperative for safety reasons) severely penalized nuclear-powered aircraft. These aircraft were as much as 80 percent heavier than a conventional aircraft, and they carried as much as 65 percent of the JP fuel of the conventional aircraft. Containment of reactor system elements has been demonstrated (Reference 19), and it is therefore believed practical to use the reactor power during takeoff and landing. Thus, a configuration with two reactors and no JP fuel was selected. With two reactors, the airplane has reactor-out flying capability.

(U) The five airplane concepts were examined to determine which aircraft might benefit from a nuclear installation. The stealth aircraft was selected for the following reasons:

1. The nuclear reactor and shielding require a large volume. The stealth aircraft appeared most capable of handling that volume.

2. Use of a high-bypass-ratio engine to eliminate the need for thrust augmentation with JP fuel or with an additional heat exchanger is desirable. The large-diameter, high-bypass-ratio engine is most easily accommodated in the stealth airplane. This type of engine, with its low exhaust gas temperatures, also reduces infrared radiation signature (IRS).

3. The lack of combustion products in the engine exhaust flow reduces IRS still more.

(U) The propulsion system selected initially and areas where further study should result in reduced vehicle weight and cost are discussed in the following paragraphs.

ENGINE CYCLE

(U) In an attempt to minimize engine size, a relatively high turbine inlet temperature of 2,400° F was selected. Current studies of nuclear power in space applications are using high-pressure helium as the reactor coolant with helium temperatures in excess of 2,400° F (Reference 20). This temperature also coincides with thte projected maximum temperature for uncooled turbines. A high overall pressure ratio of 25 was selected to minimize heat exchanger volume and weight. A moderately high bypass ratio of 4 was selected to minimize heat exchanger size and to allow a reasonable thrust/drag match at the mach 0.7 penetration. Engine characteristics are summarized in Table E-5. (U)

REACTOR AND SHIELDING

(U) Reactor power and dimensions were determined, and several approaches to shielding were examined. Unit shields (with all shielding around the reactor) were quickly eliminated from consideration because of excessive weight penalties. A range of aircraft crew and ground crew dose rates were examined with and without shield augmentation (adding shielding around the reactor) while the aircraft was on the ground. Reactor and dhielding weights and dimensions are shown in Tables E-6 and E-7, respectively, for four configurations:

1. With augmentation and ground crew dose rate of 1 r/hr

2. With augmentation and ground crew dose rate of 5 mr/hr

3. Without augmentation and with ground crew dose rate of 1 r/hr

4. Without augmentation and with ground crew dose rate of 5 mr/hr

Figures E-6 and E-7 show schematically the crew shield and the reactor shield assembly, respectively.

(U) For all these configurations, the aircraft crew dose rate was 5 mr/hr. Ground crew dose rates are for 30 minutes after reactor shutdown at a distance of 20 feet from the center of the reactors. In all cases, airport personnel at a distance of one-half mile during takeoff would receive less than 5 mr/hr.

(U) The 1 r/hr dose rate is somewhat high and therefore was considered only to show trends. Of the two cases with 5 mr dose rate, the unaugmented case requires extremely heavy shielding. Thus, the case of greatest interest is that with a ground crew dose rate of 5 mr/hr with shield augmentation. The augmentation would require some special handling procedures. The reactor shield would be designed with a shell container such that material such as mercury, lead shot, or steel shot could be "poured" into the shell and surround the reactor. The augmentation material could then be removed just prior to flight. While some special handling is required for this concept, it does provide an aircraft with essentially infinite range/duration capability, with only a modest increase in takeoff gross weight relative to the baseline stealth aircraft.

(U) TABLE E-5. MF78-03 ENGINE CHARACTERISTICS (U)

Sea-level static, maximum power thrust, lb	
Uninstalled	60,000
Installed	55,000
Design airflow, lb/sec	1,478
Bypass ratio	4.0
Combustor discharge temperature, °F	2,400
Overall pressure ratio	25
Fan front face diameter, in.	90
Maximum diameter (at nozzle), in.	97
Overall length, in.	243
Center of gravity, in. from fan front face	90
Dry weight, lb	7,500
Fan	7,500
Design pressure ratio	1.97
Number of stages	1
Design adiabatic efficiency	0.858
Design inlet mach number	0.55
Design outlet mach number	0.5
Hub/tip ratio	0.39
Bypass duct mach number	
Compressor	
Design corrected flow ($W\sqrt{\theta_{T2}}/\delta_{T2}$), lb/sec	168
Design pressure ratio	12.7
Number of stages	7

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(U) TABLE E-5. MF78-03 ENGINE CHARACTERISTICS (CONCL) (U)

Design adiabatic efficiency	0.87
Design inlet mach number	0.5
Design outlet mach number	0.35
Hub/Tip ratio	0.8
Maximum discharge pressure limit, psia	390
High-pressure turbine	
Design adiabatic efficiency	0.895
Stator cooling flow, % of compressor flow	0.0
Rotor cooling flow, % of compressor flow	0.0
Design discharge mach number	0.45
Number of stages	2
Low-pressure turbine	
Design adiabatic efficiency	0.91
Stator cooling flow	0
Rotor cooling flow	0
Design discharge mach number	0.45
Number of stages	2
Mixer	
Hot-stream mach number	0.30
Cold-stream mach number	0.30
Mixed-stream mach number	0.30
Hot-stream pressure loss, $\Delta P/P$	0.015
Cold-stream pressure loss (fan to mixer), $\Delta P/P$	0.025
Mixing pressure loss, $\Delta P/P$	0.02

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(U) TABLE E-6. REACTOR AND SHIELD WEIGHTS (POUNDS) (U)

Shield type	Augmented		Not augmented	
Ground crew dose rate	1 r/hr	5 mr/hr	1 r/hr	5 mr/hr
Front fixed γ	5,434	5,434	5,434	5,434
Side fixed γ	10,354	10,354	10,354	10,354
Rear fixed γ	1,729	1,729	1,729	1,729
Total fixed γ	17,517	17,517	17,517	17,517
Front aug γ	-	-	-	6,947
Side aug γ	-	-	34,380	67,010
Rear aug γ	-	-	6,505	15,280
Total augmented	-	-	40,885	89,237
Front neutron	6,666	7,955	6,666	7,955
Side neutron	9,263	11,810	9,263	11,810
Rear neutron	4,761	6,020	4,761	6,020
Neutron shield struct	3,300	4,000	3,300	4,000
Total neutron shield	23,990	29,785	23,990	29,785
Total shield	41,507	47,302	82,392	136,539
Reactor controls	6,505	6,505	6,505	6,505
Reflector	6,288	6,288	6,288	6,288
Ducting	4,500	4,500	4,500	4,500
Heat exchanger	12,000	12,000	12,000	12,000
Helium pump	2,000	2,000	2,000	2,000
Total reactor shield assy	72,800	78,595	113,685	167,832
Two assemblies	145,600	157,190	227,370	335,664
Crew shield	22,335	22,325	22,335	22,335
Total nuclear plant	167,935	179,525	249,705	358,000

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TABLE E-7. REACTOR SHIELD DIMENSIONS (INCHES)

Shield Type	Augmented		Not Augmented	
Ground crew dose rate	1 r/hr	5 mr/hr	1 r/hr	5 mr/hr
Overall length	124	130	124	130
Nominal diameter	98	104	98	104
Front γ thickness	4.4	4.4	4.4	6.9
Front γ aug thickness	0	2.5	-	-
Front neut thickness (total)	45	45	45	45
Side γ thickness	1.4	1.4	4.4	6.9
Side γ aug thickness	3.0	5.5	-	-
Side neut thickness (total)	30	30	30	30
Rear γ thickness	1.4	1.4	4.4	6.9
Rear γ aug thickness	3.0	5.5	-	-
Rear neut thickness (total)	30	30	30	30
Reactor length	36	36	36	36
Reflector thickness	6.0	6.0	6.0	6.0
Inner neut thickness	6.0	6.0	6.0	6.0
Intermediate neut thickness	4.0	4.0	4.0	4.0

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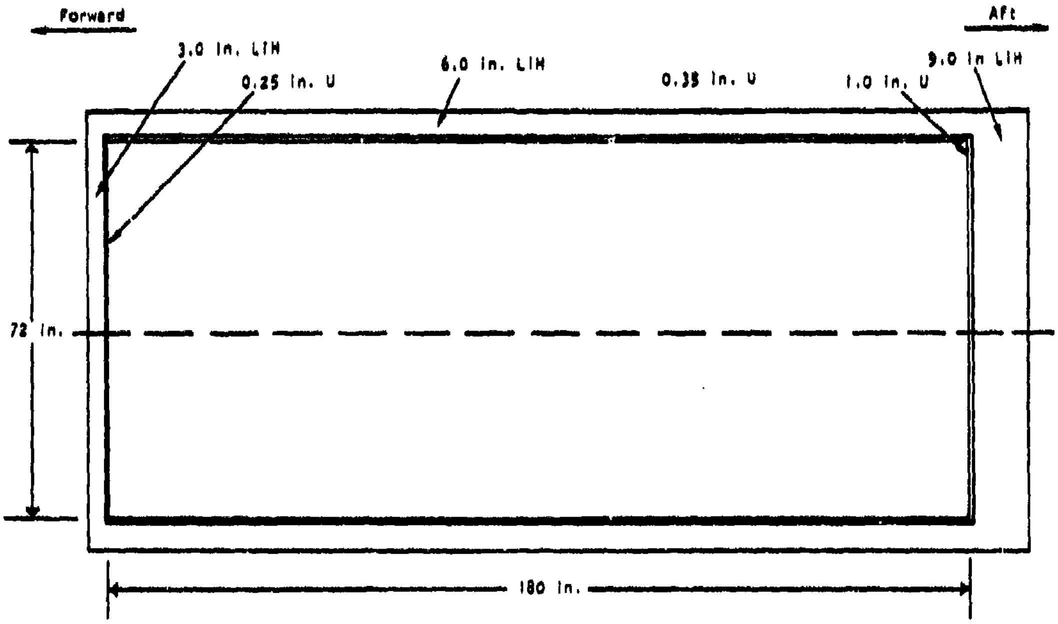

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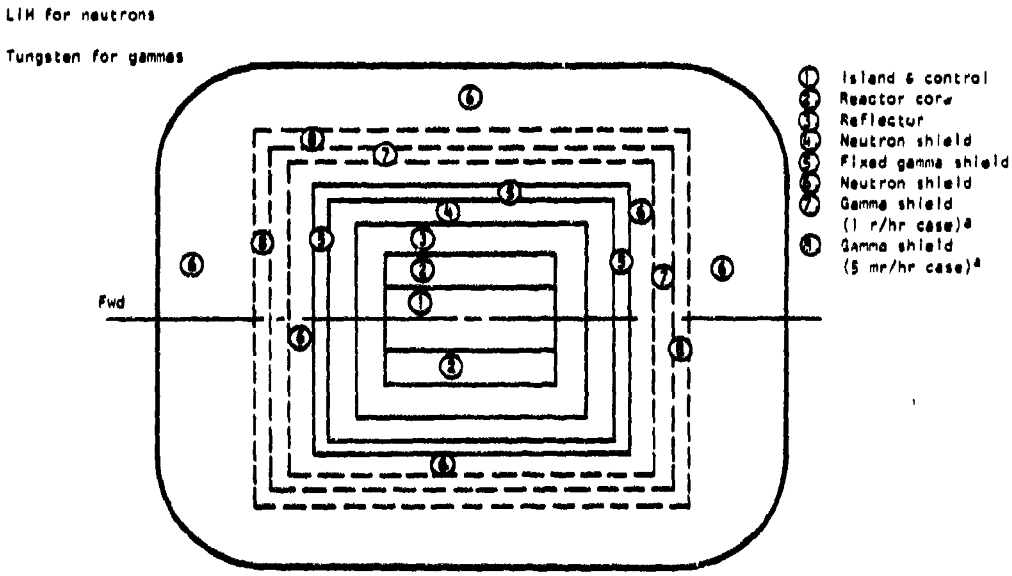
(U) Figure E-6. Schematic of crew shield. (U)



[a] Items 7 and 8 are fixed shields in the two nonaugmented cases and are regions where gamma shielding can be added on the ground in the other two cases.

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(U) Figure E-7. Schematic of reactor shield assembly. (U)

Reactor

(U) The reactor used in this study is of the reverse, folded-flow type described in Reference 21. The fuel consists of 3/16-inch-diameter uranium oxide pebbles enriched to about 15 percent in U-235. The fuel pebbles are packed into 20 beds each measuring 6 by 36 inches and having an average thickness of 2.6 inches. These 20 pebble beds are spaced radially around a central island, forming a reactor core that is 24 inches in diameter and 36 inches long.

(U) The reactor coolant is high-pressure helium that enters the side of the reactor, turns and passes through a pebble layer, then leaves the side of the reactor in a reversed direction. The helium enters the reactor at 1,200° F and in one pass is heated to 2,550° F. This results in a maximum fuel surface temperature of 2,868° F. The reactor pressure drop is 15 psi, of which 5 psi is in the fuel region.

(U) The reactor is controlled by 18 control rods that operate in the central island. The rods contain boron carbide neutron absorber material. There are six operating and 12 shim control rods.

(U) The advantages of reverse flow, folded reactors are that they are very compact and lightweight and, at the same time, have a rugged fuel element with good heat transfer characteristics. The thermal, mechanical, and nuclear features of this type of reactor were investigated in the nuclear aircraft program.

Shield

(U) The shield concept used in this study is a divided shield. The crew is protected by relatively thin layers of depleted uranium to attenuate scattered gamma rays and thicker layers of lithium hydride to remove neutrons. The crew shield was held fixed at 22,335 pounds for all four cases.

(U) The shielding around the reactor is tungsten (or a similar dense material) for gamma rays, and lithium hydride (LiH) for neutrons. A 6-inch reflector of beryllium oxide is placed around the reactor and contributes to the shield attenuation.

(U) All four cases have an inner gamma shielding layer surrounding the reactor — front, sides, and rear. A layer of LiH about 6 inches thick is between the reflector and this gamma shield to reduce the generation of secondary gammas. The two nonaugmented cases have a second fixed gamma shield that is outside the first. The purpose of this shield is to reduce the dose rate to the ground crew to 5 mr/hr at a distance of 20 feet from the reactors one-half hour after shutdown of both reactors. Since this shield is not particularly useful in reducing the dose received by the flight crew, the presence of this shield during flight represents a weight penalty. (U)

(U) In the two augmented cases, the outer gamma shield is present during ground operations but is removed for flight operations, at least when high performance is desired. The shield can be put in place or removed by being fluidized, such as using liquid mercury or shot made with lead, tungsten, or depleted uranium. The difference in weight between one shield with the augmented shield being either in or out is 89,237 pounds for the case when the ground crew receives 5 mr/hr.

HELIUM HEAT TRANSPORT SYSTEM

(U) Several nuclear powerplant cycles were given consideration. The direct air cycle where the compressor discharge airflow is passed through the reactor and then to the turbine was rejected because of the possible safety problems arising in the event of fuel element failure. Liquid-metal-cooled reactors used in an indirect cycle can, in principle, lead to lightweight powerplants. However, liquid-metal systems would have difficulty reaching the desired cycle temperatures. In addition, the complexity and safety problems of liquid-metal systems in a military aviation environment are formidable.

(U) The selected system uses high-pressure helium to cool the reactor and deliver heat to the engine. This cycle has some of the simplicity of the direct air cycle and the lightweight features of the liquid-metal cycles. At high pressure, helium has good heat transfer characteristics. It is noncorrosive and has a negligible nuclear effect on the reactor. Any radioactive particles released by the fuel elements will be contained by the closed helium loop.

AIRCRAFT PROPULSION IMPROVEMENTS

(U) During the trade study, several areas were identified where refinements could be made to reduce the aircraft gross weight. It was found that the aircraft drag characteristics were such that an engine cycle with higher bypass ratio or lower turbine inlet temperature could be used. The engine cycle has a large impact on the heat exchanger weight and volume. For example, changing turbine inlet temperature from 2,300° to 2,200° F with a cross-counter flow heat exchanger resulted in a reduction in heat exchanger weight from 22,000 to 12,000 pounds. Turbine temperature reduction would also aid in the selection and cost of the helium ducting. The helium flow rate also has a large impact on heat exchanger weight. By increasing the helium flow rate from 67 to 134 lb/sec, the weight of a counterflow heat exchanger was reduced from 22,000 to 13,500 pounds. Other parameters which affect heat exchanger and engine weights include compressor discharge temperature and pressure, air-side heat exchanger pressure loss, and helium-side heat exchanger pressure loss. Thus, significant improvements in the total propulsion system would be expected with additional effort in these areas. (U)

(U) Aircraft thrust-to-weight and wing-loading ratios were held at the baseline values for this trade study. Reoptimization of these parameters with the new engine characteristics should result in vehicle weight improvements. Additionally, a relaxation of takeoff distance from 6,000 feet to, say, 7,000 or 8,000 feet would reduce weight still further.

Appendix F

COSTING DATA

ISADS LOW COST D645-1 — RDT&E LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS — 03/13/78

WORK BREAKDOWN STRUCTURE	THOUSANDS OF HOURS			
	ENG.	SHOP	TOOL.	MFGR.
TOTAL PROGRAM	16600.07	5184.62	9987.43	9313.95
AIR VEHICLE	7082.45	690.01	9987.43	5983.82
AIRFRAME	7082.45	690.01	8689.07	3907.44
BASIC STRUCTURE	1863.07	0.0	8689.07	3907.44
FUSELAGE	1055.67	0.0	4872.98	2299.80
WING	447.91	0.0	2117.34	933.49
EMPENNAGE	182.03	0.0	878.89	287.22
NACELLES	177.60	0.0	819.86	386.93
B.S. INTEG, ASSY.	0.0	0.0	0.0	0.0
LANDING GEAR	35.95	0.0	0.0	0.0
PROPULSION SYSTEM INSTALL	174.84	0.0	0.0	0.0
FUEL SYSTEM	232.65	0.0	0.0	0.0
ELECTRICAL SYSTEM	195.92	0.0	0.0	0.0
SECONDARY POWER	10.00	0.0	0.0	0.0
HYDRAULIC POWER	257.40	0.0	0.0	0.0
ENVIRONMENTAL CONTROL	617.48	0.0	0.0	0.0
CREW ACCOMMODATIONS	90.00	0.0	0.0	0.0
CONTROLS & DISPLAYS	171.75	0.0	0.0	0.0
FLIGHT CONTROLS	142.30	0.0	0.0	0.0
A/F INTER, ASSY, INSTALL & CO	3331.50	690.01	0.0	0.0
ENGINEERING TECHNOLOGIES	2269.20	690.01	0.0	0.0
WEIGHT CONTROL	54.15	0.03	0.0	0.0
VIBRATION & FLUTTER	312.29	42.47	0.0	0.0
AERODYNAMICS	138.07	0.04	0.0	0.0
THERMODYNAMICS	953.25	3.81	0.0	0.0
STRUCTURES	810.64	643.65	0.0	0.0
DESIGN SUPPORT TECHNOLOGIES	371.59	0.0	0.0	0.0
A/F ASSY, INSTALL & CO	688.71	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY, INSTALL	0.0	0.0	1298.37	2076.39

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AIRCRAFT:ISADS LOW COST D645-1 — RDT&E LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS — 03/13/78

WORK BREAKDOWN STRUCTURE	THOUSANDS OF HOURS			
	ENG.	SHOP	TOOL.	MFGR.
TEST & EVALUATION	4526.66	4444.62	0.0	2439.49
WIND TUNNEL	76.63	1.53	0.0	0.0
FATIGUE ARTICLE TEST	558.92	1504.05	0.0	1341.89
STATIC ARTICLE TEST	665.77	1110.95	0.0	1097.60
GROUND TEST	1713.26	434.68	0.0	0.0
MOCKUP & SIMULATORS	354.12	1031.20	0.0	0.0
FLIGHT TEST	1357.96	410.10	0.0	0.0
TEST INTEGRATION, EVAL & SUPPO	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	1229.10	0.0	0.0	0.0
SPARES & REPAIR PARTS	33.24	0.0	0.0	390.74
TRAINING	325.79	0.0	0.0	0.0
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	3090.07	0.0	0.0	0.0
DATA	313.75	0.0	0.0	0.0

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AIRCRAFT:ISADS LOW COST D665-1 RDT&E COST FOR 4 PROTOTYPE AIRCRAFTS 03/13/78
ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TOTAL PROGRAM COST INCLUDE FEE								1754787.0
TOTAL PROGRAM COST INCLUDE G&A	366702.2	111727.7	229519.1	210981.4	62756.4	99932.7	29006.2	1651026.0
TOTAL PROG. INCL. MATL. BURDEN	349965.4	105403.4	215527.4	199039.1	59204.1	94191.8	26420.9	1548223.0
TOTAL PROGRAM COST LESS G&A	345965.6	105403.6	216527.4	199039.1	53821.9	85619.8	24014.0	1371876.0
AIR VEHICLE	147597.9	14027.9	216527.4	127074.2	3590.3	68713.4	24014.0	1163852.0
AIRFRAME	147597.9	14027.4	188378.8	83501.9	3590.3	68713.4	20617.3	526427.9
BASIC STRUCTURE	38876.3	0.0	188378.8	83501.9	0.0	20070.2	20617.3	351394.4
FUSELAGE	21999.1	0.0	105446.1	49146.8	0.0	3759.5	10928.5	191678.9
WING	9832.3	0.0	45903.9	19946.4	0.0	12137.9	5547.4	92869.8
EMPENNAGE	3799.6	0.0	19094.6	6138.0	0.0	3221.2	2302.7	34509.9
NACELLES	3701.3	0.0	17774.6	8704.8	0.0	992.5	1838.7	32939.6
B.S. INTEG. ASSY.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LANDING GEAR	749.2	0.0	0.0	0.0	0.0	7344.4	0.0	8093.6
PROPULSION SYSTEM INSTALL	3643.7	0.0	0.0	0.0	0.0	0.0	0.0	3643.7
FUEL SYSTEM	4848.3	0.0	0.0	0.0	0.0	3055.9	0.0	7904.2
ELECTRICAL SYSTEM	4074.6	0.0	0.0	0.0	0.0	4847.9	0.0	8922.5
SECONDARY POWER	208.4	0.0	0.0	0.0	0.0	1770.0	0.0	1996.4
HYDRAULIC POWER	5366.2	0.0	0.0	0.0	0.0	1362.7	0.0	6726.9
ENVIRONMENTAL CONTROL	12869.2	0.0	0.0	0.0	0.0	11943.9	0.0	24812.1
CREW ACCOMMODATIONS	1062.0	0.0	0.0	0.0	0.0	2974.0	0.0	3616.0
CONTROLS & DISPLAYS	3579.2	0.0	0.0	0.0	0.0	4234.0	0.0	7813.2
FLIGHT CONTROLS	2965.6	0.0	0.0	0.0	0.0	11504.6	0.0	14470.2
A/F INTEG. ASSY. INSTALL & CO	84428.3	14027.9	0.0	0.0	3590.3	0.0	0.0	87046.4
ENGINEERING TECHNOLOGIES	47290.0	14027.9	0.0	0.0	3590.3	0.0	0.0	64908.2
WEIGHT CONTROL	1128.4	0.7	0.0	0.0	2.6	0.0	0.0	1131.8
VIBRATION & FLUTTER	6504.1	863.4	0.0	0.0	537.3	0.0	0.0	7904.8
AERODYNAMICS	2894.0	0.8	0.0	0.0	24.9	0.0	0.0	2919.7
THERMODYNAMICS	19865.7	77.5	0.0	0.0	579.6	0.0	0.0	20522.8
STRUCTURES	16893.8	13085.4	0.0	0.0	2445.9	0.0	0.0	32425.0
DESIGN SUPPORT TECHNOLOGIES	7785.6	0.0	0.0	0.0	0.0	0.0	0.0	7785.6
A/F ASSY. INSTALL & CO	14352.7	0.0	0.0	0.0	0.0	0.0	0.0	14352.7
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	292000.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	249501.9
A/V INTEGRATION, ASSY. INSTALL	0.0	0.0	28148.6	44372.4	0.0	0.0	3401.7	75922.6

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AIRCRAFT:ISADS LOW COST D665-1 RDT&E COST FOR 4 PROTOTYPE AIRCRAFTS 03/13/78
ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TEST & EVALUATION	94335.2	91375.6	0.0	62914.7	50231.6	10035.1	0.0	308792.1
WIND TUNNEL	1597.0	31.2	0.0	0.0	24376.9	0.0	0.0	26004.6
FATIGUE ARTICLE TEST	11667.9	30577.4	0.0	28674.1	2340.3	5017.5	0.0	78263.2
STATIC ARTICLE TEST	9706.6	22583.6	0.0	34138.5	2199.5	5017.5	0.0	73649.6
GROUND TEST	35704.0	8881.7	0.0	0.0	1428.6	0.0	0.0	46014.3
MOCKUP & SIMULATORS	7379.9	20964.4	0.0	0.0	13686.1	0.0	0.0	42024.3
FLIGHT TEST	28299.9	8337.4	0.0	0.0	6196.7	0.0	0.0	42834.0
TEST INTEGRATION, EVAL & SUPPO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	25593.9	0.0	0.0	0.0	0.0	0.0	0.0	25593.9
SPARES & REPAIR PARTS	693.7	0.0	0.0	8350.2	0.0	6871.3	0.0	15915.2
TRAINING	6709.5	0.0	0.0	0.0	0.0	0.0	0.0	6709.5
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	64397.1	0.0	0.0	0.0	0.0	0.0	0.0	64397.1
DATA	6538.6	0.0	0.0	0.0	0.0	0.0	0.0	6538.6

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AIRCRAFT: ISADS LOW COST D649-1
ALL COSTS IN MILLIONS AND IN 1977 DOLLARS

PRODUCTION COST FOR 250 UNITS 03/13/78
UNIT AVG. FLYAWAY COST 31.567

WORK BREAKDOWN STRUCTURE

	LABOR COST					MATERIAL COST		TOTAL
	MFG.	TOOL.	ENG.	QUAL.	QA&A	MFG.	TOOL.	COST
TOTAL PROGRAM COST INCLUDING FEE	1756.93	412.49	163.35	210.33	249.55	1110.41	45.20	6313.36
TOTAL PROGRAM COST INCLUDING G&A	1597.71	374.90	148.50	191.21	224.86	1004.45	41.09	5959.64
TOTAL PROGRAM COST LESS G&A	1906.80	353.69	140.09	183.39	214.02	952.33	39.76	5751.27
AIR VEHICLE	-1906.80	353.69	140.09	130.39	214.02	452.33	33.76	5751.27
AIRFRAME	1185.34	320.24	115.76	150.39	179.14	452.33	35.10	2562.28
BASIC STRUCTURE	464.53	320.24	82.86	41.62	134.29	215.14	35.10	1676.77
FUSELAGE	403.49	172.96	41.04	23.98	66.16	43.60	14.91	709.31
WING	172.82	74.98	17.64	10.00	28.46	177.26	8.22	439.37
EMPENNAGE	81.96	31.12	8.02	4.07	12.99	32.18	3.41	174.75
NACELLES	64.78	29.03	7.04	3.47	11.35	13.12	3.18	137.67
BASIC STRUCTURE ASSEMBLY	120.52	12.56	9.17	0.0	15.33	0.0	1.37	198.88
LANDING GEAR	0.0	0.0	0.0	1.20	0.0	100.39	0.0	101.90
FUEL SYSTEM	15.65	0.0	1.44	5.20	1.01	4.90	0.0	33.99
FLIGHT VEHICLE POWER	217.14	0.0	15.64	10.34	25.05	170.01	0.0	436.17
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	17.79	0.0	192.56	0.0	206.33
CREW ACCOMMODATIONS	40.75	0.0	3.44	1.35	5.34	0.0	0.0	36.92
CONTROLS AND DISPLAYS	0.0	0.0	0.0	7.12	0.0	49.74	0.0	46.85
FLIGHT CONTROLS	57.29	0.0	4.15	3.18	5.61	178.82	0.0	240.05
ARMAMENT	0.0	0.0	0.0	0.67	0.0	35.21	0.0	35.88
AIR INDUCTION CONTROL SYSTEM	0.0	0.0	0.0	17.32	0.0	0.0	0.0	17.32
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	76.59	0.0	0.0	0.0	76.59
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	47.59	0.0	0.0	0.0	47.59
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	10.20	0.0	0.0	0.0	10.20
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	18.80	0.0	0.0	0.0	18.80
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	999.21
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1370.00
A/V INTEGRATION, ASSY, INSTALL	321.47	33.44	24.31	0.0	40.85	0.3	3.66	423.79

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AIRCRAFT: ISADS LOW COST D649-1 03/13/78

AIRCRAFT WEIGHTS - IN POUNDS

	AL	TI	ST	HC	GR	B	SA	TOTAL
FUSELAGE	19483.	0.	136.	0.	1633.	454.	0.	22681.
FRAME/LONG	19483.	0.	136.	0.	0.	0.	0.	19619.
SKIN-STRGR	0.	0.	0.	0.	0.	295.	0.	295.
BOND HONEY	0.	0.	0.	0.	1633.	159.	0.	1792.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		0.						0.
MISC								975.
WING	773.	0.	50.	0.	16382.	354.	0.	18082.
SKIN-STRGR	0.	0.	0.	0.	15225.	0.	0.	15225.
MULTI-SPAR	181.	0.	56.	0.	0.	0.	0.	239.
BOND HONEY	562.	0.	0.	0.	1157.	390.	0.	2045.
BRAZE HONEY		0.	0.				0.	1.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		0.						0.
MISC								[illegible]
EMPENNAGE	316.	0.	4.	0.	4065.	134.	0.	4721.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	42.	0.	4.	0.	3569.	0.	0.	3621.
BOND HONEY	274.	0.	0.	0.	444.	139.	0.	[illegible]
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
MISC								142.
SUPERPLASTIC		0.						0.
NACELLE	2543.	114.	382.	0.	663.	0.	0.	[illegible]
FRAME/LONG	801.	0.	382.	0.	660.	0.	0.	1843.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	1744.	0.	0.	0.	0.	0.	0.	1744.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		114.						114.
MISC								114.

WEIGHT DATA - IN POUNDS

AMPR WEIGHT	76675.
STRUCTURE WT	40975.
STRUCTURAL HONE WT	0.
SYSTEM HONE WT	0.
LANDING GEAR WT	1367?.
FUEL SYSTEM WT	1469.
ELECTRICAL SYSTEM WT	3611.
HYDRAULIC SYSTEM WT	835.
AUX POWER SYSTEM WT	100.
FCS WT	4399.
CREW ACCOM WT	2475.
CONTROL & DISPLAY WT	855.
FLIGHT CONTROL WT	2055.
ARMAMENT WT	1165.
AICS MECHANISM WT	0.
EQUIPMENT WT	14445.
ENGINE WT	9607.
EMPTY WT	100040.
FUEL WT	148243.
TOGW	317439.

DESIGN VARIABLES

WING AREA-SQ FT	1924.
EMPENNAGE AREA-SQ FT	505.
WETTED AREA-SQ FT	9673.
WING + HORIZ AREA	2430.
WING SPAN-FT	128.0
HORIZ SPAN-FT	45.0
OVERALL LENGTH-FT	120.0
ASPECT RATIO	8.00
DYNAMIC PRESSURE	1070.
MAX VELOCITY	0.95
ENGINES PER A/C	2.
A/C THRUST - LBS	97100.
MAX GRES	5.00

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AIRCRAFT/ISADS LOW COST D665-1
COSTS IN THOUSANDS AND IN 1977 DOLLARS - NO MFG

PAGE 4
RAW MATERIAL COST FOR 200 AIRCRAFT

MATERIAL/PROCESS	FUSL.	WING	EMP.	NAC.	MULT.
ALUMINUM:					
SKIN	0.	140.	74.	440.	1.067
SHEET	6942.	172.	87.	840.	1.067
PLATE	0.	224.	53.	0.	1.067
EXTRUSION	4758.	188.	71.	515.	1.077
FORGING	15457.	92.	19.	634.	1.079
CORE	2367.	2333.	1049.	2107.	1.115
TITANIUM:					
SKIN	0.	0.	0.	331.	1.132
SHEET	0.	0.	0.	697.	1.132
PLATE	0.	0.	0.	0.	1.132
EXTRUSION	0.	0.	0.	0.	1.132
FORGING	0.	0.	0.	0.	1.132
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	0.	0.	1.115
STEEL:	656.	196.	36.	1364.	1.047
BORON:	0.	0.	0.	0.	1.112
GRAPHITE:	7727.	108390.	26471.	4462.	1.112
FIBERGLASS:					
SHEET	1740.	1312.	623.	0.	1.047
CORE	123.	907.	145.	0.	1.115
SUPER ALLOYS:					
SKIN	0.	0.	0.	0.	1.132
SHEET	0.	0.	0.	0.	1.132
PLATE	0.	0.	0.	0.	1.132
EXTRUSION	0.	0.	0.	0.	1.132
FORGING	0.	0.	0.	0.	1.770
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	0.	0.	1.115
MISCELLANEOUS:	22.	2327.	420.	909.	1.306

OTHER INPUT DATA:

NORMAL FORCE ON AERO SURFACES	9.00
MAXIMUM MACH NUMBER	0.[illegible]
LANDING SINK RATE-FT/SEC	10.0
ENGINES PER AIRCRAFT	2.
TOTAL SLS THRUST/ENG - LBS	[illegible]
TOTAL THRUST/ACFT -LBS	[illegible]
INITIAL PRODN RATE-ACFT/MO	2.
FINAL PRODN RATE-ACFT/MO	4.
YEAR PRODN COMMENCES	1981.
NUMBER OF CREW PER ACFT	2.
FLEXIBILITY COEFFICIENT	1.46

RATE DATA:

MANUFACTURING LABOR & BURDEN	21.37
TOOLING LABOR & BURDEN	21.60
PLANNING LABOR & BURDEN	20.77
ENGINEERING LABOR & BURDEN	20.66
QERA LABOR & BURDEN	21.05
MFG QERA	21.00
TOOLING QERA	21.08
MFG - PERCENT	10.00
G&A - PERCENT	6.00
FEE - PERCENT	10.00

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AIRCRAFT/ISADS LOW COST D665-1
PRODUCTION HOURS DATA FOR 200 UNITS

03/13/78

WORK BREAKDOWN STRUCTURE	MFG.	TOOL.	PLNG.	ENGR.	QERA.	TOTAL
	PRODUCTION MAN-HOURS IN MILLIONS					
TOTAL PROGRAM HOURS	70.510	16.314	6.745	8.656	10.153	112.387
AIR VEHICLE	70.510	16.314	6.745	8.656	10.163	112.387
AIRFRAME	55.467	14.771	5.573	8.656	8.221	92.669
BASIC STRUCTURE	40.707	14.771	3.969	1.997	6.575	66.941
FUSELAGE	18.879	7.960	1.976	1.132	3.141	33.068
WING	8.087	3.458	0.850	0.480	1.391	14.227
EMPENNAGE	3.835	1.436	0.386	0.109	0.617	6.469
NACELLES	3.245	1.339	0.330	0.100	0.539	5.672
BASIC STRUCTURE ASSEMBLY	5.640	0.578	0.459	0.0	0.728	7.389
LANDING GEAR	0.0	0.0	0.0	0.058	0.0	0.058
FUEL SYSTEM	0.792	0.0	0.069	0.240	0.086	1.137
FLIGHT VEHICLE POWER	10.161	0.0	0.793	0.498	1.104	12.599
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	0.662	0.0	0.667
CREW ACCOMMODATIONS	2.197	0.0	0.166	0.161	0.246	2.769
CONTROLS AND DISPLAYS	0.0	0.0	0.0	0.341	0.0	0.341
FLIGHT CONTROLS	2.581	0.0	0.200	0.153	0.314	3.347
ARMAMENT	0.0	0.0	0.0	0.032	0.0	0.032
AIR INDUCTION CONTROL SYSTEM	0.0	0.0	0.0	0.831	0.0	0.831
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	3.679	0.0	3.679
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	2.286	0.0	2.284
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	0.489	0.0	0.489
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	0.402	0.0	0.402
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY, INSTALL	15.043	1.542	1.177	0.0	1.941	19.648

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ISADS LOW COST
COSTS IN FY 1977 MILLION DOLLARS

03/22/78
PAGE 1

LIFE CYCLE COST	16753.71
RDTE	3152.71
AIRFRAME	1279.04
PROPULSION	246.67
AVIONICS	292.00
OTHER	1335.00
ACQUISITION	8226.57
PRODUCTION	7848.15
FLYAWAY	6886.60
INITIAL SPARES	578.69
INITIAL OSE	217.99
TRAINING EQUIPMENT	89.53
TECHNICAL DATA	75.75
OTHER INVESTMENT	378.42
TRANSPORTATION	156.96
INITIAL PERSONNEL ACQUISITION	87.24
INITIAL PERSONNEL TRAINING	134.22
FACILITIES	0.0
TOTAL OPERATIONS FOR 15 YEARS	5374.43
RECURRING INVESTMENT & MISC. LOGISTICS	3185.05
COMMON OSE	231.00
AVIATION FUEL	781.63
BASE LEVEL MAINTENANCE MATERIAL	323.37
DEPOT LEVEL MAINTENANCE	858.11
CLASS IV MODIFICATIONS	406.20
TRAINING MUNITIONS	0.06
REPLENISHMENT SPARES	577.44
VEHICULAR EQUIPMENT	7.09
PAY AND ALLOWANCES	1741.82
IND. BOS/RPM SUPPORT	31.31
MEDICAL SUPPORT	75.04
PERSONNEL SUPPORT (PCS MOVES)	59.72
PERSONNEL ACQUISITION AND TRAINING	281.50

TOTAL PRODUCTION AIRCRAFT	200
TOTAL UE	175
COMMAND SUPPORT	12
ATTRITION	13
TOTAL PROTOTYPE AIRCRAFT	4

UNIT AVERAGE FLYAWAY COST	34.433
AIRFRAME FLYAWAY	19.735
PROPULSION FLYAWAY	4.848
AVIONICS FLYAWAY	6.850
OTHER FLYAWAY	3.000

OPERATIONS DATA:	
UE PER SQUADRON	15.0
UTIL RATE FHRS/UE/MONTH	33.3
CREW RATIO	2.0
PILOTS/CREW	2.0
OTHER OFFICERS/CREW	1.0
MAINTENANCE MAN HOURS/FHR	26.3
UNIT MAINT MEN/UE	10.0
FUEL FLOW GPH	1692.0
REPL SPARES $/FHR	550.0
BASE MAINT MTL $/FHR	308.0
DEPOT MAINT $/FHR	590.0
DEPOT MAINT $/UE/YR	91000.0
COMMON OSE $/UE/YR	88000.0

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ISADS LOW COST

03/22/78
PAGE 2

DESIGN INPUTS:

TAKEOFF GROSS WEIGHT LBS.	312663.
EMPTY WEIGHT LBS.	98241.
OPER WEIGHT LBS.	75593.
EQUIPMENT GROUP WEIGHT LBS.	27645.
INSTRUMENTS WEIGHT LBS.	885.
HYDRAULICS/PNEUMATICS LBS.	818.
ELECTRICAL GROUP WEIGHT LBS.	5494.
AVIONICS (INSTALLED) LBS.	3140.
S.S THRUST PER ENGINE LBS.	47212.
ENGINES PER AIRCRAFT	2.
MAXIMUM SPEED MACH	0.95
DYNAMIC PRESSURE LBS./SQ FT	1070.

PPE PERSONNEL/SQDN	OFFICERS	AIRMEN	CIVILIANS
AIRCREW	90		
MAINTENANCE	10	372	5
OVERHEAD	3	3	0
SECURITY	1	146	0
WING/BASE STAFF	30	37	1
PPE TOTAL	134	558	6
SPE PERSONNEL/SQDN			
BOS/RPM	3	84	18
MEDICAL	3	8	3
SPE TOTAL	6	92	21

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FROM ... DDC

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AIRCRAFT: ISADS LOW WEIGHT 3449-6 RDTE COST FOR 4 PROTOTYPE AIRCRAFTS 03/20/78
ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TOTAL PROGRAM COST INCLUDE FEE								1530443.0
TOTAL PROGRAM COST INCLUDE G&A	272770.2	72018.0	195600.9	210604.4	53607.2	100186.7	21097.4	1454021.0
TOTAL PROG. INCL. MATL. BURDEN	257832.1	68793.6	184529.1	198683.6	53476.9	94510.8	19893.8	1403363.0
TOTAL PROGRAM COST LESS G&A	257802.1	68790.6	184529.1	198683.6	48549.9	85923.4	18095.3	1358107.0
AIR VEHICLE	103617.1	9967.4	184529.1	127649.7	2386.9	67531.7	18095.3	1039557.1
AIRFRAME	133747.1	9967.4	160960.6	85352.7	2386.9	67531.7	15186.3	447632.2
BASIC STRUCTURE	22831.5	0.0	160940.4	83352.7	0.0	23277.2	15186.3	305188.1
FUSELAGE	6133.3	0.0	70305.6	38318.4	0.0	1159.7	5679.1	121595.0
WING	11379.7	0.0	39127.2	19912.7	0.0	18763.5	4727.6	93903.6
EMPENNAGE	2779.9	0.0	16238.6	6127.0	0.0	1661.2	1962.4	28765.1
NACELLES	3042.6	0.0	34877.1	19304.4	0.0	1692.8	2817.3	61434.2
B.S. INTEG, ASSY.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LANDING GEAR	600.2	0.0	0.0	0.0	0.0	5799.1	0.0	6399.3
PROPULSION SYSTEM INSTALL	2259.1	0.0	0.0	0.0	0.0	0.0	0.0	2259.1
FUEL SYSTEM	4443.3	0.0	0.0	0.0	0.0	2933.3	0.0	7376.6
ELECTRICAL SYSTEM	3438.7	0.0	0.0	0.0	0.0	4164.5	0.0	7603.1
SECONDARY POWER	488.4	0.0	0.0	0.0	0.0	1861.1	0.0	2349.5
HYDRAULIC POWER	4711.7	0.0	0.0	0.0	0.0	1207.7	0.0	5919.4
ENVIRONMENTAL CONTROL	3085.6	0.0	0.0	0.0	0.0	11943.8	0.0	15029.4
CREW ACCOMMODATIONS	1042.0	0.0	0.0	0.0	0.0	2574.0	0.0	3616.0
CONTROLS & DISPLAYS	2219.1	0.0	0.0	0.0	0.0	4234.0	0.0	6453.0
FLIGHT CONTROLS	2443.5	0.0	0.0	0.0	0.0	9537.0	0.0	12980.5
A/R INTEG, ASSY, INSTALL & CO	56364.0	9967.4	0.0	0.0	2386.9	0.0	0.0	68718.2
ENGINEERING TECHNOLOGIES	43546.5	9967.4	0.0	0.0	2386.9	0.0	0.0	55900.7
WEIGHT CONTROL	1704.5	1.0	0.0	0.0	4.2	0.0	0.0	1709.6
VIBRATION & FLUTTER	-2393.9	-317.6	0.0	0.0	-197.6	0.0	0.0	-2909.1
AERODYNAMICS	11328.9	3.3	0.0	0.0	97.4	0.0	0.0	11429.6
THERMODYNAMICS	19733.6	77.0	0.0	0.0	575.7	0.0	0.0	20386.3
STRUCTURES	13173.3	10203.6	0.0	0.0	1907.2	0.0	0.0	25284.2
DESIGN SUPPORT TECHNOLOGIES	4507.7	0.0	0.0	0.0	0.0	0.0	0.0	4507.7
A/R ASSY, INSTALL & CO	8309.9	0.0	0.0	0.0	0.0	0.0	0.0	8309.9
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	292000.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	233744.0
A/V INTEGRATION, ASSY, INSTALL	0.0	0.0	23298.8	44293.1	0.0	0.0	3599.0	71190.9

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AIRCRAFT: ISADS LOW WEIGHT 3449-6 RDTE COST FOR 4 PROTOTYPE AIRCRAFTS 03/20/78
ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TEST & EVALUATION	81080.9	58823.2	0.0	62702.4	46163.0	11638.6	0.0	260408.1
WIND TUNNEL	16987.1	331.4	0.0	0.0	28216.6	0.0	0.0	45535.1
FATIGUE ARTICLE TEST	6849.5	17980.8	0.0	28624.9	1379.7	5819.3	0.0	60654.2
STATIC ARTICLE TEST	5707.9	13280.1	0.0	34077.5	1293.4	5819.3	0.0	60178.2
GROUND TEST	24777.1	6238.2	0.0	0.0	1303.4	0.0	0.0	32318.6
MOCKUP & SIMULATORS	5183.4	14724.5	0.0	0.0	9611.2	0.0	0.0	29519.1
FLIGHT TEST	21276.1	6268.1	0.0	0.0	4654.7	0.0	0.0	32198.9
TEST INTEGRATION, EVAL & SUPPO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	17975.9	0.0	0.0	0.0	0.0	0.0	0.0	17975.9
SPARES & REPAIR PARTS	487.2	0.0	0.0	8335.3	0.0	6753.2	0.0	15575.7
TRAINING	4768.7	0.0	0.0	0.0	0.0	0.0	0.0	4768.7
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	45229.9	0.0	0.0	0.0	0.0	0.0	0.0	45229.9
DATA	4592.4	0.0	0.0	0.0	0.0	0.0	0.0	4592.4

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AIRCRAFT: ISAOS LOW WEIGHT D643-6 — PRODUCTION COST FOR 200 UNITS — 03/20/78
ALL COSTS IN MILLIONS AND IN 1977 DOLLARS — UNIT AVG. FLYAWAY COST 27.619

WORK BREAKDOWN STRUCTURE	LABOR COST MFG.	TOOL.	ENGG.	ENGR.	QC&A	MATERIAL COST MFG.	TOOL.	TOTAL COST
TOTAL PROGRAM COST INCLUDING FEE	1327.13	353.79	125.25	144.71	193.31	1073.72	38.77	5493.90
TOTAL PROGRAM COST INCLUDING G&A	1206.49	321.59	113.86	131.55	175.73	975.66	35.24	5147.89
TOTAL PROGRAM COST LESS G&A	1138.20	303.39	107.42	124.11	165.79	920.43	33.25	5020.33
AIR VEHICLE	1138.20	303.39	107.42	124.11	165.79	920.43	33.25	5020.33
AIRFRAME	891.23	275.13	88.55	124.11	134.39	920.43	30.15	2463.62
BASIC STRUCTURE	594.70	275.13	61.38	23.20	99.88	295.20	30.15	1339.31
FUSELAGE	109.69	115.99	15.82	6.97	25.79	12.55	12.67	298.68
WING	295.19	64.32	25.07	12.20	40.67	200.69	7.05	639.18
EMPENNAGE	34.29	26.70	4.24	1.16	6.99	16.35	2.53	93.16
NACELLES	64.12	57.34	8.51	3.26	13.92	25.11	6.28	178.55
BASIC STRUCTURE ASSEMBLY	97.42	11.16	7.44	0.0	12.51	0.0	1.22	129.75
LANDING GEAR	0.0	0.0	0.0	0.97	0.0	79.26	0.0	80.23
FUEL SYSTEM	15.02	0.0	1.37	4.76	1.73	9.12	0.0	32.09
FLIGHT VEHICLE POWER	187.16	0.0	13.68	8.96	21.59	150.83	0.0	382.02
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	1.31	0.0	192.54	0.0	193.84
CREW ACCOMMODATIONS	46.73	0.0	3.44	1.35	5.39	0.0	0.0	58.92
CONTROLS AND DISPLAYS	0.0	0.0	0.0	7.12	0.0	49.74	0.0	56.85
FLIGHT CONTROLS	47.59	0.0	5.45	2.64	5.49	146.55	0.0	207.72
ARMAMENT	0.0	0.0	0.0	1.67	0.0	35.21	0.0	39.88
AIR INDUCTION CONTROL SYSTEM	0.0	0.0	0.0	15.62	0.0	0.0	0.0	15.62
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	53.51	0.0	0.0	0.0	53.51
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	34.54	0.0	0.0	0.0	34.54
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	6.67	0.0	0.0	0.0	6.67
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	12.30	0.0	0.0	0.0	12.30
PROPULSION (OFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	857.76
AVIONICS (OFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1370.00
A/V INTEGRATION, ASSY, INSTALL	246.99	28.25	18.87	0.0	31.71	0.0	3.10	328.96

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AIRCRAFT: ISAOS LOW WEIGHT D643-6 — 03/20/78

AIRCRAFT WEIGHTS - IN POUNDS

	AL	TI	ST	BO	GR	EG	SA	TOTAL
FUSELAGE	4930.	0.	0.	0.	652.	165.	0.	5876.
FRAME/LONG	4530.	0.	0.	0.	652.	0.	0.	5183.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	1.
BOND HONEY	0.	0.	0.	0.	0.	165.	0.	165.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		0.						0.
MISC								529.
WING	0.	1924.	136.	0.	23739.	733.	0.	27161.
SKIN-STRGR	0.	0.	0.	0.	18578.	0.	0.	18578.
MULTI-SPAR	0.	1521.	136.	0.	0.	0.	0.	1657.
BOND HONEY	0.	0.	0.	0.	5161.	733.	0.	5894.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		407.						407.
MISC								635.
EMPENNAGE	0.	211.	0.	0.	2076.	0.	0.	2348.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	0.	5.	0.	0.	620.	0.	0.	625.
BOND HONEY	0.	0.	0.	0.	1455.	0.	0.	1455.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
MISC								69.
SUPERPLASTIC		198.						198.
NACELLE	0.	2029.	292.	0.	504.	0.	0.	2915.
FRAME/LONG	0.	539.	292.	0.	504.	0.	0.	1335.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	0.	0.	0.	0.	0.	0.	0.	0.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		1490.						1490.
MISC								91.

WEIGHT DATA - IN POUNDS	
AMPR WEIGHT	62475.
STRUCTURE WT	46767.
STRUCTURAL HONE WT	0.
SYSTEM HONE WT	0.
LANDING GEAR WT	8629.
FUEL SYSTEM WT	1897.
ELECTRICAL SYSTEM WT	4820.
HYDRAULIC SYSTEM WT	740.
AUX POWER SYSTEM WT	311.
ECS WT	4099.
CREW ACCOM WT	7479.
CONTROL & DISPLAY WT	855.
FLIGHT CONTROL WT	2379.
ARMAMENT WT	1169.
AICS MECHANISM WT	0.
EQUIPMENT WT	10955.
ENGINE WT	7973.
EMPTY WT	83069.
FUEL WT	190810.
TOGW	292570.

DESIGN VARIABLES	
WING AREA-SQ FT	3333.
EMPENNAGE AREA-SQ FT	506.
WETTED AREA-SQ FT	9210.
WING + HORIZ AREA	3523.
WING SPAN-FT	100.0
HORIZ SPAN-FT	18.0
OVERALL LENGTH-FT	48.1
ASPECT RATIO	3.00
DYNAMIC PRESSURE	1070.
MAX VELOCITY	0.98
ENGINES PER A/C	2.
A/C THRUST - LBS	[illegible]
MAX GEES	5.00

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ISADS LOW WEIGHT D645-6 RDT&E LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS 03/20/78

WORK BREAKDOWN STRUCTURE	THOUSANDS OF HOURS			
	ENG.	SHOP	TOOL.	MFGR.
TOTAL PROGRAM	12370.54	3383.70	8511.50	9297.30
AIR VEHICLE	4974.43	490.28	8511.50	5973.13
AIRFRAME	4974.43	490.28	7405.00	3900.46
BASIC STRUCTURE	1095.56	0.0	7405.00	3900.46
FUSELAGE	294.30	0.0	3242.83	1792.64
WING	546.05	0.0	1804.44	931.81
EMPENNAGE	109.21	0.0	749.01	286.71
NACELLES	146.00	0.0	1628.72	889.30
B.S. INTEG, ASSY.	0.0	0.0	0.0	0.0
LANDING GEAR	28.80	0.0	0.0	0.0
PROPULSION SYSTEM INSTALL	108.4[illegible]	0.0	0.0	0.0
FUEL SYSTEM	213.21	0.0	0.0	0.0
ELECTRICAL SYSTEM	165.00	0.0	0.0	0.0
SECONDARY POWER	[illegible]	0.0	0.0	0.0
HYDRAULIC POWER	226.09	0.0	0.0	0.0
ENVIRONMENTAL CONTROL	148.06	0.0	0.0	0.0
CREW ACCOMMODATIONS	[illegible]	0.0	0.0	0.0
CONTROLS & DISPLAYS	106.48	0.0	0.0	0.0
FLIGHT CONTROLS	118.21	0.0	0.0	0.0
A/F INTEG, ASSY, INSTALL & CO	2704.61	490.28	0.0	0.0
ENGINEERING TECHNOLOGIES	2089.56	490.28	0.0	0.0
WEIGHT CONTROL	81.79	0.05	0.0	0.0
VIBRATION & FLUTTER	-114.87	-15.62	0.0	0.0
AERODYNAMICS	563.62	0.16	0.0	0.0
THERMODYNAMICS	946.91	3.79	0.0	0.0
STRUCTURES	632.12	501.90	0.0	0.0
DESIGN SUPPORT TECHNOLOGIES	216.33	0.0	0.0	0.0
A/F ASSY, INSTALL & CO	398.75	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY, INSTALL	0.0	0.0	1106.50	2072.68

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AIRCRAFT/ISADS LOW WEIGHT D645-6 RDT&E LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS 03/20/78

WORK BREAKDOWN STRUCTURE	THOUSANDS OF HOURS			
	ENG.	SHOP	TOOL.	MFGR.
TEST & EVALUATION	3990.64	2893.42	0.0	2934.13
WIND TUNNEL	815.12	16.30	0.0	0.0
FATIGUE ARTICLE TEST	328.67	884.45	0.0	1339.49
STATIC ARTICLE TEST	273.85	653.23	0.0	1594.64
GROUND TEST	1233.11	336.84	0.0	0.0
MOCKUP & SIMULATORS	249.72	724.28	0.0	0.0
FLIGHT TEST	1023.93	318.32	0.0	0.0
TEST INTEGRATION, EVAL & SUPPO	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	862.57	0.0	0.0	0.0
SPARES & REPAIR PARTS	23.38	0.0	0.0	393.05
TRAINING	228.82	0.0	0.0	0.0
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	2170.34	0.0	0.0	0.0
DATA	220.37	0.0	0.0	0.0

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AIRCRAFT(ISADS LOW WEIGHT D645-6   03/23/78
PRODUCTION HOURS DATA FOR 200 UNITS

PRODUCTION MAN-HOURS IN MILLIONS

WORK BREAKDOWN STRUCTURE	MFG.	TOOL.	PLNG.	ENGR.	QERA	TOTAL
TOTAL PROGRAM HOURS	53.261	13.994	5.172	5.955	7.872	86.254
AIR VEHICLE	53.261	13.994	5.172	5.955	7.872	86.254
AIRFRAME	41.703	12.689	4.263	5.955	6.367	70.978
BASIC STRUCTURE	27.829	12.689	2.941	1.113	4.743	49.315
FUSELAGE	5.133	5.332	0.762	0.315	1.225	12.766
WING	13.532	2.967	1.207	0.585	1.931	20.222
EMPENNAGE	1.604	1.221	0.204	0.056	0.332	3.420
NACELLES	3.001	2.665	0.410	0.156	0.661	6.873
BASIC STRUCTURE ASSEMBLY	4.559	0.515	0.358	0.0	0.596	6.125
LANDING GEAR	0.0	0.0	0.0	0.046	0.0	0.046
FUEL SYSTEM	0.703	0.0	0.066	0.229	0.082	1.080
FLIGHT VEHICLE POWER	8.758	0.0	0.649	0.433	1.025	10.862
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	0.159	0.0	0.159
CREW ACCOMMODATIONS	2.187	0.0	0.166	0.161	0.256	2.769
CONTROLS AND DISPLAYS	0.0	0.0	0.0	0.341	0.0	0.341
FLIGHT CONTROLS	2.227	0.0	0.166	0.127	0.261	2.781
ARMAMENT	0.0	0.0	0.0	0.032	0.0	0.032
AIR INDUCTION CONTROL SYSTEM	0.0	0.0	0.0	0.750	0.0	0.750
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	2.568	0.0	2.568
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	1.657	0.0	1.657
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	0.320	0.0	0.320
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	0.590	0.0	0.590
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY, INSTALL	11.558	1.305	0.909	0.0	1.506	15.277

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AIRCRAFT(ISADS LOW WEIGHT D645-6
COSTS IN THOUSANDS AND IN 1977 DOLLARS - AT MOC

PAGE 4
RAW MATERIAL COST FOR 200 AIRCRAFT

MATERIAL/PROCESS	FUSL.	WING	CAN.	NAC.	MOBI.
ALUMINUM:					
SKIN	0.	0.	0.	0.	1.067
SHEET	1619.	0.	0.	0.	1.067
PLATE	0.	0.	0.	0.	1.067
EXTRUSION	1106.	0.	0.	0.	1.077
FORGING	3593.	0.	0.	0.	1.079
CORE	0.	7481.	2110.	0.	1.115
TITANIUM:					
SKIN	0.	4695.	981.	4305.	1.132
SHEET	0.	8655.	1225.	11259.	1.132
PLATE	0.	1577.	5.	0.	1.132
EXTRUSION	0.	1737.	5.	1232.	1.132
FORGING	0.	1659.	5.	1176.	1.132
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	0.	0.	1.115
STEEL:	0.	485.	0.	1342.	1.067
BORON:	0.	0.	0.	0.	1.112
GRAPHITE:	4409.	140998.	11090.	3409.	1.112
FIBERGLASS:					
SHEET	543.	2419.	0.	0.	1.067
CORE	127.	967.	0.	0.	1.115
SUPER ALLOYS:					
SKIN	0.	0.	0.	0.	1.132
SHEET	0.	0.	0.	0.	1.132
PLATE	0.	0.	0.	0.	1.132
EXTRUSION	0.	0.	0.	0.	1.132
FORGING	0.	0.	0.	0.	1.079
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	0.	0.	1.115
MISCELLANEOUS:	12.	7772.	307.	401.	1.096

OTHER INPUT DATA:

NORMAL FORCE ON AERO SURFACES	9.00
MAXIMUM MACH NUMBER	0.95
LANDING SINK RATE-FT/SEC	10.0
ENGINES PER AIRCRAFT	2.
TOTAL SLS THRUST/ENG - LBS	41252.
TOTAL THRUST/ACFT -LBS	82504.
INITIAL PRODN RATE-ACFT/MO	2.
FINAL PRODN RATE-ACFT/MO	4.
YEAR PRODN COMMENCES	1985.
NUMBER OF CREW PER ACFT	3.
FLEXIBILITY COEFFICIENT	1.00

RATE DATA

MANUFACTURING LABOR & BURDEN	21.37
TOOLING LABOR & BURDEN	21.68
PLANNING LABOR & BURDEN	20.77
ENGINEERING LABOR & BURDEN	20.84
QERA LABOR & BURDEN	21.06
MFG QERA	21.06
TOOLING QERA	21.36
MFG - PERCENT	10.00
QEA - PERCENT	6.00
FEE - PERCENT	10.00

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1540S LOW WEIGHT
COSTS IN FY 1977 MILLION DOLLARS

03/22/78
PAGE 1

LIFE CYCLE COST	15246.49
RDT&E	2865.44
AIRFRAME	1004.70
PROPULSION	233.74
AVIONICS	292.00
OTHER	1335.00
ACQUISITION	7292.22
PRODUCTION	6933.48
FLYAWAY	6084.00
INITIAL SPARES	511.25
INITIAL OSE	192.23
TRAINING EQUIPMENT	79.09
TECHNICAL DATA	66.92
OTHER INVESTMENT	358.74
TRANSPORTATION	138.67
INITIAL PERSONNEL ACQUISITION	86.70
INITIAL PERSONNEL TRAINING	133.37
FACILITIES	0.0
TOTAL OPERATIONS FOR 15 YEARS	5088.83
RECURRING INVESTMENT & MISC. LOGISTICS	2934.43
COMMON OSE	202.12
AVIATION FUEL	756.96
BASE LEVEL MAINTENANCE MATERIAL	323.37
DEPOT LEVEL MAINTENANCE	771.69
CLASS IV MODIFICATIONS	358.86
TRAINING MUNITIONS	0.06
REPLENISHMENT SPARES	514.45
VEHICULAR EQUIPMENT	6.93
PAY AND ALLOWANCES	1712.38
MED. RDS/RPM SUPPORT	30.70
MEDICAL SUPPORT	73.74
PERSONNEL SUPPORT (PCS MOVES)	58.89
PERSONNEL ACQUISITION AND TRAINING	278.70

TOTAL PRODUCTION AIRCRAFT	200
TOTAL UE	175
COMMAND SUPPORT	12
ATTRITION	13
TOTAL PROTOTYPE AIRCRAFT	4
UNIT AVERAGE FLYAWAY COST	30.420
AIRFRAME FLYAWAY	16.281
PROPULSION FLYAWAY	4.289
AVIONICS FLYAWAY	6.850
OTHER FLYAWAY	3.000

OPERATIONS DATA:

UE PER SQUADRON	15.0
UTIL RATE FHRS/UE/MONTH	33.3
CREW RATIO	2.0
PILOTS/CREW	2.0
OTHER OFFICERS/CREW	1.0
MAINTENANCE MAN HOURS/FHR	24.9
MUNIT MAINT MEN/UE	10.0
FUEL FLOW GPH	1638.6
REPL SPARES $/FHR	490.0
BASE MAINT MTL $/FHR	308.0
DEPOT MAINT $/FHR	540.0
DEPOT MAINT $/UE/YR	78000.0
COMMON OSE $/UE/YR	77000.0

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1540S LOW WEIGHT

03/22/78
PAGE 2

DESIGN INPUTS:

TAKEOFF GROSS WEIGHT LBS.	292570.
EMPTY WEIGHT LBS.	83865.
DCPR WEIGHT LBS.	62476.
EQUIPMENT GROUP WEIGHT LBS.	26890.
INSTRUMENTS WEIGHT LBS.	895.
HYDRAULICS/PNEUMATICS LBS.	740.
ELECTRICAL GROUP WEIGHT LBS.	4820.
AVIONICS (INSTALLED) LBS.	9140.
SLS THRUST PER ENGINE LBS.	41252.
ENGINES PER AIRCRAFT	2.
MAXIMUM SPEED MACH	0.95
DYNAMIC PRESSURE LBS./SQ FT	1070.

PPE PERSONNEL/SQDN	OFFICERS	AIRMEN	CIVILIANS
AIRCREW	90		
MAINTENANCE	10	340	4
OVERHEAD	3	3	0
SECURITY	1	146	0
WING/BASE STAFF	30	37	1
PPE TOTAL	134	546	5
SPE PERSONNEL/SQDN			
RDS/RPM	3	82	17
MEDICAL	3	8	3
SPE TOTAL	6	90	20

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ISADS MIN PEN SPEED D645-3 — ROTEE LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS — 03/16/78

WORK BREAKDOWN STRUCTURE	ENG.	SHOP	TOOL.	MFGR.
	THOUSANDS OF HOURS			
TOTAL PROGRAM	51344.51	19019.12	15115.51	15279.91
AIR VEHICLE	22444.47	1916.77	15115.51	9816.70
AIRFRAME	22444.47	1906.77	13150.49	6410.30
BASIC STRUCTURE	5283.46	0.0	13150.49	6413.31
FUSELAGE	4827.93	0.0	8592.37	4375.23
WING	298.41	0.0	3204.49	1531.41
EMPENNAGE	121.30	0.0	1330.17	471.20
NACELLES	35.83	0.0	63.47	32.47
B.S. INTEG. ASSY.	0.0	0.0	0.0	0.0
LANDING GEAR	199.52	0.0	0.0	0.0
PROPULSION SYSTEM INSTALL	685.63	0.0	0.0	0.0
FUEL SYSTEM	579.24	0.0	0.0	0.0
ELECTRICAL SYSTEM	493.39	0.0	0.0	0.0
SECONDARY POWER	11.00	0.0	0.0	0.0
HYDRAULIC POWER	1065.40	0.0	0.0	0.0
ENVIRONMENTAL CONTROL	2654.00	0.0	0.0	0.0
CREW ACCOMMODATIONS	50.00	0.0	0.0	0.0
CONTROLS & DISPLAYS	673.50	0.0	0.0	0.0
FLIGHT CONTROLS	963.30	0.0	0.0	0.0
A/F INTEG. ASSY. INSTALL & CO	9787.06	1906.77	0.0	0.0
ENGINEERING TECHNOLOGIES	6119.94	1906.77	0.0	0.0
WEIGHT CONTROL	198.13	0.12	0.0	0.0
VIBRATION & FLUTTER	1166.76	158.60	0.0	0.0
AERODYNAMICS	400.09	0.12	0.0	0.0
THERMODYNAMICS	2164.54	9.66	0.0	0.0
STRUCTURES	2190.42	1739.19	0.0	0.0
DESIGN SUPPORT TECHNOLOGIES	1358.73	0.0	0.0	0.0
A/F ASSY. INSTALL & CO	2308.40	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0
A/V INTEGRATION. ASSY. INSTALL	0.0	0.0	1965.02	3406.40

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AIRCRAFT:ISADS MIN PEN SPEED — ROTEE LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS — 03/16/78

WORK BREAKDOWN STRUCTURE	ENG.	SHOP	TOOL.	MFGR.
	THOUSANDS OF HOURS			
TEST & EVALUATION	13083.43	13112.35	0.0	4822.18
WIND TUNNEL	179.71	3.89	0.0	0.0
FATIGUE ARTICLE TEST	1585.06	4269.34	0.0	2201.42
STATIC ARTICLE TEST	1320.87	3180.26	0.0	2620.76
GROUND TEST	5429.32	1384.48	0.0	0.0
MOCKUP & SIMULATORS	1122.22	3267.91	0.0	0.0
FLIGHT TEST	3446.28	1340.77	0.0	0.0
TEST INTEGRATION. EVAL & SUPPO	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	3891.87	0.0	0.0	0.0
SPARES & REPAIR PARTS	135.49	0.0	0.0	641.03
TRAINING	1032.49	0.0	0.0	0.0
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	9793.52	0.0	0.0	0.0
DATA	494.24	0.0	0.0	0.0

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AIRCRAFT: ISADS MIN PEN SPEED — ROTOR COST FOR 4 PROTOTYPE AIRCRAFTS — 03/16/78

ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TOTAL PROGRAM COST INCLUDE FEE								3347224.0
TOTAL PROGRAM COST INCLUDE G&A	1134220.0	323659.1	347366.2	346123.6	129934.9	143536.9	45982.8	3149559.0
TOTAL PROG. INCL. MATL. BURDEN	1070219.0	305338.7	327703.9	326531.6	122580.1	135412.1	43381.0	3009701.0
TOTAL PROGRAM COST LESS G&A	1070219.0	305338.7	327703.9	326531.6	111436.4	123101.9	39436.3	2982301.0
AIR VEHICLE	467742.8	38764.6	327703.9	209782.9	10014.0	93704.1	39436.3	1869887.0
AIRFRAME	467742.8	38764.6	285102.4	136988.2	10014.0	93704.1	34288.0	1066604.0
BASIC STRUCTURE	110107.4	0.0	285102.4	136988.2	0.0	40054.9	34288.0	606540.9
FUSELAGE	100614.1	0.0	185418.4	93498.7	0.0	16187.0	22242.2	417957.2
WING	6218.9	0.0	69473.2	32726.2	0.0	22139.8	8395.8	138953.6
EMPENNAGE	2528.0	0.0	28838.0	10069.6	0.0	1448.7	3485.0	46369.2
NACELLES	746.6	0.0	1375.9	693.8	0.0	279.5	165.1	3261.0
B.S. INTEG. ASSY.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LANDING GEAR	4158.0	0.0	0.0	0.0	0.0	10212.7	0.0	14370.6
PROPULSION SYSTEM INSTALL	14288.6	0.0	0.0	0.0	0.0	0.0	0.0	14288.6
FUEL SYSTEM	12071.4	0.0	0.0	0.0	0.0	6060.6	0.0	18132.0
ELECTRICAL SYSTEM	10282.2	0.0	0.0	0.0	0.0	4974.0	0.0	15256.3
SECONDARY POWER	208.4	0.0	0.0	0.0	0.0	4182.5	0.0	4390.9
HYDRAULIC POWER	22202.9	0.0	0.0	0.0	0.0	1989.4	0.0	24192.3
ENVIRONMENTAL CONTROL	55309.2	0.0	0.0	0.0	0.0	12688.0	0.0	67997.2
CREW ACCOMMODATIONS	1042.0	0.0	0.0	0.0	0.0	916.5	0.0	1958.5
CONTROLS & DISPLAYS	14035.7	0.0	0.0	0.0	0.0	4729.2	0.0	18764.8
FLIGHT CONTROLS	20075.1	0.0	0.0	0.0	0.0	7896.6	0.0	27971.7
A/F INTER, ASSY, INSTALL & CO	203962.2	38764.6	0.0	0.0	10014.0	0.0	0.0	252740.8
ENGINEERING TECHNOLOGIES	127539.4	38764.6	0.0	0.0	10014.0	0.0	0.0	176317.9
WEIGHT CONTROL	4129.0	2.4	0.0	0.0	10.1	0.0	0.0	4141.5
VIBRATION & FLUTTER	24715.4	3226.0	0.0	0.0	2007.3	0.0	0.0	29948.6
AERODYNAMICS	8337.8	2.4	0.0	0.0	71.7	0.0	0.0	8411.9
THERMODYNAMICS	45109.0	176.0	0.0	0.0	1316.0	0.0	0.0	46601.1
STRUCTURES	45648.3	35357.8	0.0	0.0	6608.9	0.0	0.0	87614.9
DESIGN SUPPORT TECHNOLOGIES	28315.8	0.0	0.0	0.0	0.0	0.0	0.0	28315.8
A/F ASSY, INSTALL & CO	48107.1	0.0	0.0	0.0	0.0	0.0	0.0	48107.1
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	194400.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	484339.1
A/V INTEGRATION, ASSY, INSTALL	0.0	0.0	42601.6	72794.7	0.0	0.0	5148.3	120544.5

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AIRCRAFT: ISADS MIN PEN SPEED — ROTOR COST FOR 4 PROTOTYPE AIRCRAFTS — 03/16/78

ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TEST & EVALUATION	272658.5	266374.1	0.0	103049.9	101422.4	20027.5	0.0	763732.4
WIND TUNNEL	3748.2	73.1	0.0	0.0	24912.5	0.0	0.0	28730.7
FATIGUE ARTICLE TEST	33332.2	86714.2	0.0	47044.3	6653.9	10013.7	0.0	183458.3
STATIC ARTICLE TEST	27526.8	64044.9	0.0	56005.7	6237.5	10013.7	0.0	163828.5
GROUND TEST	113146.9	28146.4	0.0	0.0	4527.2	0.0	0.0	145820.4
MOCKUP & SIMULATORS	23387.1	66436.7	0.0	0.0	43365.2	0.0	0.0	133189.0
FLIGHT TEST	71820.3	21159.0	0.0	0.0	15726.1	0.0	0.0	108705.3
TEST INTEGRATION, EVAL & SUPPO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	81106.6	0.0	0.0	0.0	0.0	0.0	0.0	81106.6
SPARES & REPAIR PARTS	2198.4	0.0	0.0	13698.8	0.0	9370.4	0.0	25267.6
TRAINING	21516.2	0.0	0.0	0.0	0.0	0.0	0.0	21516.2
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	204076.1	0.0	0.0	0.0	0.0	0.0	0.0	204076.1
DATA	20721.0	0.0	0.0	0.0	0.0	0.0	0.0	20721.0

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AIRCRAFT: ISADS MIN PEN SPEED — PRODUCTION COST FOR 200 UNITS — 03/16/78

ALL COSTS IN MILLIONS AND IN 1977 DOLLARS — UNIT AVG. FLYAWAY COST 49.948

WORK BREAKDOWN STRUCTURE	LABOR COST MFG.	TOOL.	PLNG.	ENGR.	QC&A	MATERIAL COST MFG.	TOOL.	TOTAL COST
TOTAL PROGRAM COST INCLUDING FEE	2992.89	762.34	297.93	580.90	431.57	1820.05	83.52	9988.96
TOTAL PROGRAM COST INCLUDING GGA	2720.81	692.76	270.85	527.73	392.61	1660.04	75.92	9354.89
TOTAL PROGRAM COST LESS GGA	2566.80	653.55	255.52	497.85	370.39	1566.08	71.63	8995.99
AIR VEHICLE	2566.80	653.55	255.52	497.85	370.39	1566.08	71.63	8995.99
AIRFRAME	2159.54	595.82	223.65	497.85	316.85	1566.08	65.30	5425.09
BASIC STRUCTURE	1715.90	595.82	166.44	118.02	265.67	476.15	65.30	3403.31
FUSELAGE	992.07	369.78	100.73	107.85	156.48	197.10	40.53	1964.53
WING	498.13	138.55	44.05	6.67	73.21	261.41	15.18	1037.19
EMPENNAGE	25.54	57.51	5.84	2.71	9.49	14.51	6.30	121.90
NACELLES	8.05	2.74	0.79	0.80	1.24	3.14	0.33	17.07
BASIC STRUCTURE ASSEMBLY	192.11	27.23	15.03	0.0	25.26	0.0	2.98	262.62
LANDING GEAR	0.0	0.0	0.0	4.46	0.0	139.58	0.0	144.04
FUEL SYSTEM	31.04	0.0	3.04	12.94	3.58	18.83	0.0	69.43
FLIGHT VEHICLE POWER	239.40	0.0	18.90	35.04	27.61	308.91	0.0	629.87
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	59.29	0.0	204.53	0.0	263.82
CREW ACCOMMODATIONS	44.37	0.0	3.28	3.35	5.12	0.0	0.0	56.12
CONTROLS AND DISPLAYS	0.0	0.0	0.0	4.53	0.0	55.56	0.0	60.08
FLIGHT CONTROLS	104.86	0.0	8.71	21.52	12.10	327.30	0.0	474.49
ARMAMENT	0.0	0.0	0.0	0.67	0.0	35.21	0.0	35.88
AIR INDUCTION CONTROL SYSTEM	23.98	0.0	3.60	27.74	2.77	0.0	0.0	58.09
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	210.30	0.0	0.0	0.0	210.30
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	127.77	0.0	0.0	0.0	127.77
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	30.58	0.0	0.0	0.0	30.58
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	51.95	0.0	0.0	0.0	51.95
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2102.18
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	912.00
A/V INTEGRATION, ASSY, INSTALL	407.26	57.73	31.87	0.0	53.54	0.0	6.33	556.73

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AIRCRAFT: ISADS MIN PEN SPEED — 03/16/78

AIRCRAFT WEIGHTS - IN POUNDS

	AL	TI	ST	BO	GR	EG	SA	TOTAL
FUSELAGE	39030.	7144.	232.	0.	9295.	348.	0.	58080.
FRAME/LONG	39030.	7144.	232.	0.	7086.	348.	0.	53840.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	0.	0.	0.	0.	2207.	0.	0.	2207.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		0.						0.
MISC								2033.
WING	0.	9414.	229.	0.	22128.	0.	0.	32686.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	0.	0.	229.	0.	19808.	0.	0.	20037.
BOND HONEY	0.	0.	0.	0.	2321.	0.	0.	2321.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		9414.						9414.
MISC								915.
EMPENNAGE	0.	196.	29.	0.	1829.	0.	0.	2114.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	0.	0.	0.	0.	628.	0.	0.	628.
BOND HONEY	0.	6.	29.	0.	1201.	0.	0.	1236.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
MISC								0.
SUPERPLASTIC		149.						149.
NACELLE	0.	53.	44.	0.	322.	0.	0.	431.
FRAME/LONG	0.	0.	44.	0.	306.	0.	0.	350.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	0.	0.	0.	0.	16.	0.	0.	16.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		53.						53.
MISC								12.

WEIGHT DATA - IN POUNDS	
AMPR WEIGHT	130356.
STRUCTURE WT	111348.
STRUCTURAL HONE WT	0.
SYSTEM HONE WT	0.
LANDING GEAR WT	14844.
FUEL SYSTEM WT	3935.
ELECTRICAL SYSTEM WT	5797.
HYDRAULIC SYSTEM WT	1219.
AUX POWER SYSTEM WT	1884.
ECS WT	5200.
CREW ACCOM WT	2350.
CONTROL & DISPLAY WT	955.
FLIGHT CONTROL WT	5233.
ARMAMENT WT	1165.
AICS MECHANISM WT	3233.
EQUIPMENT WT	16135.
ENGINE WT	22904.
EMPTY WT	167098.
FUEL WT	329421.
TOGW	551880.

DESIGN VARIABLES	
WING AREA-SQ FT	2799.
EMPENNAGE AREA-SQ FT	338.
WETTED AREA-SQ FT	12746.
WING + HORIZ AREA	2928.
WING SPAN-FT	129.0
HORIZ SPAN-FT	21.7
OVERALL LENGTH-FT	167.0
ASPECT RATIO	6.00
DYNAMIC PRESSURE	2133.
MAX VELOCITY	1.60
ENGINES PER A/C	4.
A/C THRUST - LBS	165564.
MAX GEES	6.10

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AIRCRAFT:ISADS MIN PEN SPEED
PRODUCTION HOURS DATA FOR 200 UNITS

03/14/78

PRODUCTION MAN-HOURS IN MILLIONS

WORK BREAKDOWN STRUCTURE	MFG.	TOOL.	PLAG.	ENGR.	QERA.	TOTAL
TOTAL PROGRAM HOURS	120.112	30.145	12.302	23.889	17.587	204.037
AIR VEHICLE	120.112	30.145	12.302	23.889	17.587	204.037
AIRFRAME	101.055	27.483	10.768	23.889	15.345	178.240
BASIC STRUCTURE	80.295	27.483	8.014	5.663	12.615	134.069
FUSELAGE	46.423	17.056	4.850	5.175	7.430	80.935
WING	23.310	6.391	2.121	0.320	3.476	35.617
EMPENNAGE	1.195	2.653	0.281	0.130	0.450	4.710
NACELLES	0.377	0.127	0.038	0.038	0.059	0.639
BASIC STRUCTURE ASSEMBLY	8.990	1.256	0.724	0.0	1.199	12.169
LANDING GEAR	0.0	0.0	0.0	0.214	0.0	0.214
FUEL SYSTEM	1.452	0.0	0.146	0.621	0.170	2.390
FLIGHT VEHICLE POWER	11.202	0.0	0.911	1.682	1.311	15.105
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	2.845	0.0	2.845
CREW ACCOMMODATIONS	2.076	0.0	0.158	0.161	0.243	2.638
CONTROLS AND DISPLAYS	0.0	0.0	0.0	0.217	0.0	0.217
FLIGHT CONTROLS	4.907	0.0	0.420	1.033	0.574	6.933
ARMAMENT	0.0	0.0	0.0	0.032	0.0	0.032
AIR INDUCTION CONTROL SYSTEM	1.122	0.0	0.175	1.331	0.131	2.758
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	10.091	0.0	10.091
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	6.131	0.0	6.131
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	1.467	0.0	1.467
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	2.493	0.0	2.493
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY, INSTALL	19.058	2.663	1.534	0.0	2.542	25.797

AIRCRAFT:ISADS MIN PEN SPEED
COSTS IN THOUSANDS AND IN 1977 DOLLARS - NO MPC

PAGE 4
RAW MATERIAL COST FOR 200 AIRCRAFT

MATERIAL/PROCESS	FLSL.	WING	CAN.	NAC.	NORT.
ALUMINUM:					
SKIN	0.	0.	0.	0.	1.067
SHEET	13946.	0.	0.	0.	1.067
PLATE	0.	0.	0.	0.	1.067
EXTRUSION	9932.	0.	0.	0.	1.077
FORGING	30993.	0.	0.	0.	1.079
CORE	3200.	3344.	1741.	23.	1.115
TITANIUM:					
SKIN	0.	27229.	446.	151.	1.132
SHEET	28999.	97319.	929.	321.	1.132
PLATE	0.	0.	0.	0.	1.132
EXTRUSION	16220.	0.	7.	0.	1.132
FORGING	19980.	0.	0.	0.	1.132
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	32.	0.	1.115
STEEL:	830.	818.	104.	156.	1.067
BORON:	0.	0.	0.	0.	1.112
GRAPHITE:	88239.	144812.	9910.	2144.	1.112
FIBERGLASS:					
SHEET	1437.	0.	0.	0.	1.067
CORE	0.	0.	0.	0.	1.115
SUPER ALLOYS:					
SKIN	0.	0.	0.	0.	1.132
SHEET	0.	0.	0.	0.	1.132
PLATE	0.	0.	0.	0.	1.132
EXTRUSION	0.	0.	0.	0.	1.132
FORGING	0.	0.	0.	0.	1.079
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	0.	0.	1.115
MISCELLANEOUS:	45.	4061.	0.	55.	1.096

OTHER INPUT DATA:

NORMAL FORCE ON AERO SURFACES	6.00
MAXIMUM MACH NUMBER	1.60
LANDING SINK RATE-FT/SEC	10.0
ENGINES PER AIRCRAFT	4.
TOTAL SLS THRUST/ENG - LBS	41391.
TOTAL THRUST/ACFT -LBS	165564.
INITIAL PRODN RATE-ACFT/MO	2.
FINAL PRODN RATE-ACFT/MO	4.
YEAR PRODN COMMENCES	1989.
NUMBER OF CREW PER ACFT	2.
FLEXIBILITY COEFFICIENT	2.23

RATE DATA

MANUFACTURING LABOR & BURDEN	21.37
TOOLING LABOR & BURDEN	21.68
PLANNING LABOR & BURDEN	20.77
ENGINEERING LABOR & BURDEN	20.84
QERA LABOR & BURDEN	21.06
MFG QERA	21.06
TOOLING QERA	21.06
MPC - PERCENT	10.00
GEA - PERCENT	6.00
FEE - PERCENT	10.00

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ISADS MINIMUM PENETRATION TIME
COSTS IN FY 1977 MILLION DOLLARS

03/22/78
PAGE 1

LIFE CYCLE COST	24500.39
RDT&E	4682.22
AIRFRAME	2668.48
PROPULSION	484.34
AVIONICS	194.40
OTHER	1335.00
ACQUISITION	12504.87
PRODUCTION	12067.51
FLYAWAY	10589.00
INITIAL SPARES	889.81
INITIAL OSE	334.57
TRAINING EQUIPMENT	137.66
TECHNICAL DATA	116.48
OTHER INVESTMENT	437.37
TRANSPORTATION	241.35
INITIAL PERSONNEL ACQUISITION	74.89
INITIAL PERSONNEL TRAINING	121.13
FACILITIES	0.0
TOTAL OPERATIONS FOR 15 YEARS	7313.30
RECURRING INVESTMENT & MISC. LOGISTICS	5252.47
COMMON OSE	354.37
AVIATION FUEL	1780.37
BASE LEVEL MAINTENANCE MATERIAL	323.37
DEPOT LEVEL MAINTENANCE	1270.41
CLASS IV MODIFICATIONS	624.58
TRAINING MUNITIONS	0.06
REPLENISHMENT SPARES	892.41
VEHICULAR EQUIPMENT	6.91
PAY AND ALLOWANCES	1640.02
MED- BOS/RPM SUPPORT	30.66
MEDICAL SUPPORT	73.19
PERSONNEL SUPPORT (PCS MOVES)	96.13
PERSONNEL ACQUISITION AND TRAINING	260.84

TOTAL PRODUCTION AIRCRAFT	200
TOTAL UE	175
COMMAND SUPPORT	12
ATTRITION	13
TOTAL PROTOTYPE AIRCRAFT	4
UNIT AVERAGE FLYAWAY COST	52.945
AIRFRAME FLYAWAY	34.874
PROPULSION FLYAWAY	10.511
AVIONICS FLYAWAY	4.560
OTHER FLYAWAY	3.000
OPERATIONS DATA:	
UE PER SQUADRON	15.0
UTIL RATE FHRS/UE/MONTH	33.3
CREW RATIO	2.0
PILOTS/CREW	2.0
OTHER OFFICERS/CREW	0.0
MAINTENANCE MAN HOURS/FHR	28.1
MUNIT MAINT MEN/UE	10.0
FUEL FLOW GPH	3854.0
REPL SPARES $/FHR	890.0
BASE MAINT MTL $/FHR	308.0
DEPOT MAINT $/FHR	820.0
DEPOT MAINT $/UE/YR	154000.0
COMMON OSE $/UE/YR	135000.0

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ISADS MINIMUM PENETRATION TIME

03/22/78
PAGE 2

DESIGN INPUTS:

TAKEOFF GROSS WEIGHT LBS.	351880.
EMPTY WEIGHT LBS.	167098.
DCPR WEIGHT LBS.	130598.
EQUIPMENT GROUP WEIGHT LBS.	29909.
INSTRUMENTS WEIGHT LBS.	955.
HYDRAULICS/PNEUMATICS LBS.	1219.
ELECTRICAL GROUP WEIGHT LBS.	5757.
AVIONICS (INSTALLED) LBS.	6085.
SLS THRUST PER ENGINE LBS.	41391.
ENGINES PER AIRCRAFT	4.
MAXIMUM SPEED MACH	1.60
DYNAMIC PRESSURE LBS./SQ FT	2133.

PPE PERSONNEL/SQDN	OFFICERS	AIRMEN	CIVILIANS
AIRCREW	60		
MAINTENANCE	11	387	5
OVERHEAD	3	3	0
SECURITY	1	146	0
WING/BASE STAFF	30	37	1
PPE TOTAL	105	573	6
SPE PERSONNEL/SQDN			
BOS/RPM	3	82	17
MEDICAL	3	8	3
SPE TOTAL	6	90	20

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ISADS STEALTH D648-4

ROTRF LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS — 03/20/78

WORK BREAKDOWN STRUCTURE	ENG.	SHOP	TOOL.	MFGR.
	THOUSANDS OF HOURS			
TOTAL PROGRAM	15945.60	3407.16	8229.66	8288.61
AIR VEHICLE	5513.19	394.77	8229.66	5325.78
AIRFRAME	5513.19	394.77	7159.81	3477.28
BASIC STRUCTURE	1059.93	0.0	7159.81	3477.28
FUSELAGE	0.0	0.0	0.0	0.0
WING	567.29	0.0	1744.69	830.71
EMPENNAGE	113.46	0.0	724.21	259.60
NACELLES	379.19	0.0	4690.91	2393.96
B.S. INTEG. ASSY.	0.0	0.0	0.0	0.0
LANDING GEAR	31.92	0.0	0.0	0.0
PROPULSION SYSTEM INSTALL	135.60	0.0	0.0	0.0
FUEL SYSTEM	239.84	0.0	0.0	0.0
ELECTRICAL SYSTEM	185.66	0.0	0.0	0.0
SECONDARY POWER	10.00	0.0	0.0	0.0
HYDRAULIC POWER	301.30	0.0	0.0	0.0
ENVIRONMENTAL CONTROL	261.38	0.0	0.0	0.0
CREW ACCOMMODATIONS	93.11	0.0	0.0	0.0
CONTROLS & DISPLAYS	133.20	0.0	0.0	0.0
FLIGHT CONTROLS	119.47	0.0	0.0	0.0
A/F INTEG. ASSY. INSTALL & CO	2986.40	394.77	0.0	0.0
ENGINEERING TECHNOLOGIES	2315.92	394.77	0.0	0.0
WEIGHT CONTROL	83.89	7.39	0.0	0.0
VIBRATION & FLUTTER	-64.99	-8.78	0.0	0.0
AERODYNAMICS	784.14	0.24	0.0	0.0
THERMODYNAMICS	1012.69	4.05	0.0	0.0
STRUCTURES	502.79	399.22	0.0	0.0
DESIGN SUPPORT TECHNOLOGIES	235.97	0.0	0.0	0.0
A/F ASSY. INSTALL & CO	438.90	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY. INSTALL	0.0	0.0	1069.84	1847.80

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AIRCRAFT/ISADS STEALTH D645-4

ROTRF LABOR HOURS FOR 4 PROTOTYPE AIRCRAFTS — 03/21/78

WORK BREAKDOWN STRUCTURE	ENG.	SHOP	TOOL.	MFGR.
	THOUSANDS OF HOURS			
TEST & EVALUATION	5647.28	3012.39	0.0	2619.80
WIND TUNNEL	2349.71	46.91	0.0	0.0
FATIGUE ARTICLE TEST	317.08	855.68	0.0	1196.16
STATIC ARTICLE TEST	264.98	611.99	0.0	1421.63
GROUND TEST	1333.64	340.08	0.0	0.0
MOCKUP & SIMULATORS	275.46	812.72	0.0	0.0
FLIGHT TEST	1119.31	335.71	0.0	0.0
TEST INTEGRATION, EVAL & SUPPO	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	455.99	0.0	0.0	0.0
SPARES & REPAIR PARTS	28.91	0.0	0.0	347.73
TRAINING	253.61	0.0	0.0	0.0
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	2109.40	0.0	0.0	0.0
DATA	244.23	0.0	0.0	0.0

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AIRCRAFT(ISAPS STEALTH D665-4 ROTEB COST FOR 4 PROTOTYPE AIRCRAFTS [illegible]
ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TOTAL PROGRAM COST INCLUDE FEE								1571631.0
TOTAL PROGRAM COST INCLUDE GFA	332363.5	73423.6	189124.2	187755.2	67341.5	93537.1	13813.6	1495522.[illegible]
TOTAL PROC. INCL. MATL. BURDEN	313950.4	69267.6	178419.1	177127.5	63529.7	85418.4	[illegible]	[illegible]
TOTAL PROGRAM COST LESS GFA	313953.4	69267.6	178419.1	177127.5	57754.3	77647.6	[illegible]	[illegible]
AIR VEHICLE	114894.7	8029.6	178419.1	113797.0	2166.2	62954.2	[illegible]	[illegible]
AIRFRAME	114894.7	9029.6	155224.6	74309.4	2166.2	62554.2	[illegible]	[illegible]
BASIC STRUCTURE	22089.0	0.0	155224.6	74309.4	0.0	17676.1	6469.5	275767.7
FUSELAGE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WING	11822.3	0.0	37824.9	17752.3	0.0	17237.1	[illegible]	89207.7
EMPENNAGE	2364.5	0.0	15700.9	5462.1	0.0	289.1	[illegible]	25714.1
NACELLES	7902.3	0.0	101609.9	51094.9	0.0	149.9	[illegible]	[illegible]
B.S. INTEG. ASSY.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LANDING GEAR	706.8	0.0	0.0	0.0	0.0	6865.6	0.0	7572.4
PROPULSION SYSTEM INSTALL	2025.9	0.0	0.0	0.0	0.0	0.0	0.0	2025.9
FUEL SYSTEM	4998.3	0.0	0.0	0.0	0.0	3197.8	0.0	8196.1
ELECTRICAL SYSTEM	3869.2	0.0	0.0	0.0	0.0	3719.5	0.0	7588.7
SECONDARY POWER	208.4	0.0	0.0	0.0	0.0	1841.1	0.0	2049.5
HYDRAULIC POWER	6279.0	0.0	0.0	0.0	0.0	1176.7	0.0	7455.7
ENVIRONMENTAL CONTROL	5447.2	0.0	0.0	0.0	0.0	11943.8	0.0	17391.0
CREW ACCOMMODATIONS	1042.0	0.0	0.0	0.0	0.0	2574.0	0.0	3616.0
CONTROLS & DISPLAYS	2775.8	0.0	0.0	0.0	0.0	4234.0	0.0	7009.8
FLIGHT CONTROLS	2406.5	0.0	0.0	0.0	0.0	9355.7	0.0	11762.1
A/F INTEG, ASSY, INSTALL & CO	62246.6	8029.6	0.0	0.0	2166.2	0.0	0.0	72438.4
ENGINEERING TECHNOLOGIES	48263.7	8029.6	0.0	0.0	2166.2	0.0	0.0	58459.5
WEIGHT CONTROL	1685.7	1.0	0.0	0.0	4.1	0.0	0.0	1690.8
VIBRATION & FLUTTER	-1346.1	-178.6	0.0	0.0	-111.1	0.0	0.0	-1635.8
AERODYNAMICS	16341.5	4.8	0.0	0.0	140.4	0.0	0.0	16486.7
THERMODYNAMICS	21136.4	82.4	0.0	0.0	615.7	0.0	0.0	21802.4
STRUCTURES	10478.2	8116.1	0.0	0.0	1517.0	0.0	0.0	20111.3
DESIGN SUPPORT TECHNOLOGIES	4917.5	0.0	0.0	0.0	0.0	0.0	0.0	4917.5
A/F ASSY, INSTALL & CO	9065.4	0.0	0.0	0.0	0.0	0.0	0.0	9065.4
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	292000.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	252167.6
A/V INTEGRATION, ASSY, INSTALL	0.0	0.0	23194.5	39487.6	0.0	0.0	[illegible]	65409.1

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AIRCRAFT(ISAPS STEALTH D665-4 ROTEB COST FOR 4 PROTOTYPE AIRCRAFTS 01/20/78
ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TEST & EVALUATION	117689.4	61242.0	0.0	55899.6	55988.1	9839.1	0.0	300257.0
~~WIND TUNNEL~~	[illegible]	953.0	0.0	0.0	36179.7	0.0	0.0	[illegible]
FATIGUE ARTICLE TEST	6626.7	17396.1	0.0	25519.2	1194.9	4619.0	0.0	[illegible]
STATIC ARTICLE TEST	5522.2	12940.3	0.0	30380.3	1291.3	4419.0	0.0	54421.2
GROUND TEST	27793.1	6913.8	0.0	0.0	1112.1	0.0	0.0	35818.9
MOCKUP & SIMULATORS	5746.7	16319.3	0.0	0.0	10652.1	0.0	0.0	32718.1
FLIGHT TEST	23118.1	6810.8	0.0	0.0	5062.0	0.0	0.0	34990.9
~~TEST INTEGRATION, EVAL & SUPPO~~	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	19922.6	0.0	0.0	0.0	0.0	0.0	0.0	19922.6
SPARES & REPAIR PARTS	[illegible]	0.0	0.0	7490.9	0.0	6290.4	0.0	14324.4
TRAINING	9209.2	0.0	0.0	0.0	0.0	0.0	0.0	9209.2
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
~~SYS. ENGR. & PROGRAM MGMT.~~	[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]
DATA	[illegible]	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]

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AIRCRAFT: ISADS STEALTH D665-6 — PRODUCTION COST FOR 200 UNITS — 03/20/78

ALL COSTS IN MILLIONS AND IN 1977 DOLLARS — UNIT AVG. FLYAWAY COST 28.770

WORK BREAKDOWN STRUCTURE	LABOR COST MFG.	TOOL.	PLNG.	ENGR.	QC&A	MATERIAL COST MFG.	TOOL.	TOTAL COST
TOTAL PROGRAM COST INCLUDING FEE	1337.77	335.43	125.23	150.69	192.56	1003.94	36.87	5754.06
TOTAL PROGRAM COST INCLUDING G&A	1216.15	305.94	113.84	136.99	175.06	912.67	33.52	5464.65
TOTAL PROGRAM COST LESS G&A	1167.31	288.53	107.40	129.24	165.15	861.01	31.62	5300.86
AIR VEHICLE	1167.31	288.53	107.40	129.24	165.15	861.01	31.62	5300.86
AIRFRAME	863.90	259.17	85.95	129.24	129.12	861.01	28.40	2356.80
BASIC STRUCTURE	567.72	259.17	58.34	21.56	94.95	195.92	28.40	1225.77
FUSELAGE	0.10	0.0	0.01	0.0	0.01	0.0	0.0	0.11
WING	477.44	61.17	37.81	12.67	62.93	191.61	6.70	849.43
EMPENNAGE	6.44	25.39	2.19	0.42	2.63	2.71	2.78	42.55
NACELLES	5.08	164.46	12.08	8.47	19.29	1.60	18.32	229.02
BASIC STRUCTURE ASSEMBLY	78.67	8.15	5.95	0.0	10.00	0.0	0.89	103.66
LANDING GEAR	0.0	0.0	0.0	1.14	0.0	93.84	0.0	94.97
FUEL SYSTEM	16.32	0.0	1.50	5.36	1.88	9.91	0.0	34.97
FLIGHT VEHICLE POWER	167.86	0.0	12.31	11.10	19.36	138.76	0.0	349.39
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	5.84	0.0	192.54	0.0	198.37
CREW ACCOMMODATIONS	46.73	0.0	3.44	3.35	5.39	0.0	0.0	58.92
CONTROLS AND DISPLAYS	0.0	0.0	0.0	7.12	0.0	49.74	0.0	56.85
FLIGHT CONTROLS	46.49	0.0	3.37	2.58	5.36	145.11	0.0	203.91
ARMAMENT	0.0	0.0	0.0	1.67	0.0	35.21	0.0	35.88
AIR INDUCTION CONTROL SYSTEM	18.77	0.0	2.45	16.44	2.17	0.0	0.0	39.83
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	54.09	0.0	0.0	0.0	54.09
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	34.22	0.0	0.0	0.0	34.22
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	6.99	0.0	0.0	0.0	6.99
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	12.88	0.0	0.0	0.0	12.88
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1200.58
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1370.00
A/V INTEGRATION, ASSY, INSTALL	283.41	29.36	21.45	0.0	36.03	0.0	3.22	373.47

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AIRCRAFT: ISADS STEALTH D665-6 — 03/20/78

AIRCRAFT WEIGHTS - IN POUNDS

	AL	TI	ST	[illegible]	[illegible]	[illegible]	[illegible]	TOTAL
FUSELAGE	0.	0.	0.	0.	0.	0.	0.	0.
FRAME/LONG	0.	0.	0.	0.	0.	0.	0.	0.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	0.	0.	0.	0.	0.	0.	0.	0.
BRAZE HONEY		0.	0.				0.	0.
FIBER BOND		0.					0.	0.
SUPERPLASTIC		0.						0.
MISC								0.
WING	[illegible]	2599.	[illegible]	0.	1738.	771.	0.	26596.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	[illegible]	1490.	[illegible]	0.	14985.	0.	0.	21216.
BOND HONEY	0.	0.	[illegible]	0.	2992.	771.	0.	1373.
BRAZE HONEY		0.	0.				0.	0.
FIBER BOND		0.					0.	0.
SUPERPLASTIC		1063.						1063.
MISC								984.
EMPENNAGE	0.	[illegible]	0.	0.	[illegible]	0.	0.	376.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	0.	6.	0.	0.	219.	0.	0.	225.
BOND HONEY	0.	0.	0.	0.	193.	0.	0.	153.
BRAZE HONEY		0.	0.				0.	0.
FIBER BOND		0.					0.	0.
MISC								13.
SUPERPLASTIC		4.						4.
NACELLE	0.	10.	13.	0.	192.	0.	0.	221.
FRAME/LONG	0.	0.	13.	0.	192.	0.	0.	215.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	0.	0.	0.	0.	0.	0.	0.	0.
BRAZE HONEY		0.	0.				0.	0.
FIBER BOND		0.					0.	0.
SUPERPLASTIC		10.						10.
MISC								7.

WEIGHT DATA - IN POUNDS	
AMPR WEIGHT	54839.
STRUCTURE WT	37199.
STRUCTURAL HONE WT	0.
SYSTEM HONE WT	0.
LANDING GEAR WT	9979.
FUEL SYSTEM WT	2354.
ELECTRICAL SYSTEM WT	4305.
HYDRAULIC SYSTEM WT	721.
AUX POWER SYSTEM WT	311.
ECS WT	4895.
CREW ACCOM WT	2475.
CONTROL & DISPLAY WT	855.
FLIGHT CONTROL WT	2320.
ARMAMENT WT	1169.
AICS MECHANISM WT	2531.
EQUIPMENT WT	18955.
ENGINE WT	11247.
EMPTY WT	79642.
FUEL WT	144882.
TOGW	302396.

DESIGN VARIABLES	
WING AREA-SQ FT	3287.
EMPENNAGE AREA-SQ FT	144.
WETTED AREA-SQ FT	7497.
WING + HORIZ AREA	3287.
WING SPAN-FT	81.0
HORIZ SPAN-FT	0.0
OVERALL LENGTH-FT	76.7
ASPECT RATIO	2.00
DYNAMIC PRESSURE	1070.
MAX VELOCITY	0.95
ENGINES PER A/C	2.
A/C THRUST - LBS	99703.
MAX GEES	5.00

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AIRCRAFT/SADS STEALTH D649-4 03/20/78
PRODUCTION HOURS DATA FOR 200 UNITS

PRODUCTION MAN-HOURS IN MILLIONS

WORK BREAKDOWN STRUCTURE	MFG.	TOOL.	PLNG.	ENGR.	QERA.	TOTAL
TOTAL PROGRAM HOURS	53.688	13.309	5.171	6.201	7.842	86.211
AIR VEHICLE	53.688	13.309	5.171	6.201	7.842	86.211
AIRFRAME	40.426	11.954	4.135	6.201	6.131	68.851
BASIC STRUCTURE	26.566	11.954	2.794	1.034	4.509	46.858
FUSELAGE	0.005	0.0	0.000	0.0	0.001	0.005
WING	22.342	2.821	1.821	0.608	2.945	30.537
EMPENNAGE	0.301	1.171	0.105	0.020	0.172	1.770
NACELLES	0.238	7.586	0.591	0.406	0.916	9.727
BASIC STRUCTURE ASSEMBLY	3.681	0.376	0.297	0.0	0.475	4.819
LANDING GEAR	0.0	0.0	0.0	0.055	0.0	0.055
FUEL SYSTEM	0.764	0.0	0.072	0.257	0.089	1.183
FLIGHT VEHICLE POWER	7.855	0.0	0.593	0.533	0.919	9.900
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	0.280	0.0	0.280
CREW ACCOMMODATIONS	2.187	0.0	0.164	0.161	0.256	2.769
CONTROLS AND DISPLAYS	0.0	0.0	0.0	0.341	0.0	0.341
FLIGHT CONTROLS	2.175	0.0	0.162	0.124	0.255	2.716
ARMAMENT	0.0	0.0	0.0	0.032	0.0	0.032
AIR INDUCTION CONTROL SYSTEM	0.879	0.0	0.118	0.789	0.103	1.888
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	2.595	0.0	2.595
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	1.642	0.0	1.642
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	0.335	0.0	0.335
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	0.618	0.0	0.618
PROPULSION (OFF)	0.0	0.0	0.0	0.0	0.0	0.0
AVIONICS (OFF)	0.0	0.0	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY, INSTALL	13.262	1.354	1.033	0.0	1.711	17.360

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AIRCRAFT/SADS STEALTH D649-4 PAGE 4
COSTS IN THOUSANDS AND IN 1977 DOLLARS - NO MPC
RAW MATERIAL COST FOR 200 AIRCRAFT

MATERIAL/PROCESS	FUSE.	WING	CAN.	NAC.	MCHT.
ALUMINUM:					
SKIN	0.	0.	0.	0.	1.067
SHEET	0.	0.	0.	0.	1.067
PLATE	0.	1612.	0.	0.	1.067
EXTRUSION	0.	636.	0.	0.	1.077
FORGING	0.	590.	0.	0.	1.079
CORE	0.	3700.	193.	0.	1.119
TITANIUM:					
SKIN	0.	7516.	26.	27.	1.132
SHEET	0.	12519.	53.	58.	1.132
PLATE	0.	1938.	8.	0.	1.132
EXTRUSION	0.	1701.	7.	0.	1.132
FORGING	0.	1423.	7.	0.	1.132
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	0.	0.	1.115
STEEL:	0.	855.	1.	47.	1.067
BORON:	0.	0.	0.	0.	1.112
GRAPHITE:	0.	134098.	2114.	1795.	1.112
FIBERGLASS:					
SHEET	0.	2944.	0.	0.	1.067
CORE	0.	596.	0.	0.	1.119
OTHER ALLOYS:					
SKIN	0.	0.	0.	0.	1.132
SHEET	0.	0.	0.	0.	1.132
PLATE	0.	0.	0.	0.	1.132
EXTRUSION	0.	0.	0.	0.	1.132
FORGING	0.	0.	0.	0.	1.079
DIFF BOND	0.	0.	0.	0.	1.035
CORE	0.	0.	0.	0.	1.119
MISCELLANEOUS:	0.	1185.	97.	29.	1.096

OTHER INPUT DATA:

NORMAL FORCE ON AERO SURFACES	5.00
MAXIMUM MACH NUMBER	0.95
LANDING SINK RATE-FT/SEC	10.0
ENGINES PER AIRCRAFT	2.
TOTAL SLS THRUST/ENG - LBS	49895.
TOTAL THRUST/ACFT -LBS	99790.
INITIAL PRODN RATE-ACFT/MO	2.
FINAL PRODN RATE-ACFT/MO	4.
YEAR PRODN COMMENCES	1985.
NUMBER OF CREW PER ACFT	2.
FLEXIBILITY COEFFICIENT	1.79

RATE DATA:

MANUFACTURING LABOR & BURDEN	21.37
TOOLING LABOR & BURDEN	21.68
PLANNING LABOR & BURDEN	20.77
ENGINEERING LABOR & BURDEN	20.84
QERA LABOR & BURDEN	21.06
MFG QERA	21.06
TOOLING QERA	21.06
MPC - PERCENT	10.00
G&A - PERCENT	6.00
FEE - PERCENT	10.00

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ISADS STEALTH
COSTS IN FY 1977 MILLION DOLLARS

03/22/78
PAGE 1

LIFE CYCLE COST	15804.05
RDTE	2906.63
AIRFRAME	1027.46
PROPULSION	252.17
AVIONICS	292.00
OTHER	1335.00
ACQUISITION	7607.26
PRODUCTION	7241.18
FLYAWAY	6394.00
INITIAL SPARES	533.94
INITIAL OSE	200.76
TRAINING EQUIPMENT	82.40
TECHNICAL DATA	69.89
OTHER INVESTMENT	366.08
TRANSPORTATION	144.82
INITIAL PERSONNEL ACQUISITION	87.17
INITIAL PERSONNEL TRAINING	134.09
FACILITIES	0.0
TOTAL OPERATIONS FOR 19 YEARS	9240.17
RECURRING INVESTMENT & MISC. LOGISTICS	3104.98
COMMON OSE	212.62
AVIATION FUEL	837.98
BASE LEVEL MAINTENANCE MATERIAL	323.37
DEPOT LEVEL MAINTENANCE	813.69
CLASS IV MODIFICATIONS	374.70
TRAINING MUNITIONS	0.06
REPLENISHMENT SPARES	535.45
VEHICULAR EQUIPMENT	7.03
PAY AND ALLOWANCES	1738.42
IND. BOS/RPM SUPPORT	31.23
MEDICAL SUPPORT	74.85
PERSONNEL SUPPORT (PCS MOVES)	59.60
PERSONNEL ACQUISITION AND TRAINING	201.08

TOTAL PRODUCTION AIRCRAFT	200
TOTAL UE	175
COMMAND SUPPORT	12
ATTRITION	13
TOTAL PROTOTYPE AIRCRAFT	4

UNIT AVERAGE FLYAWAY COST	31.770
AIRFRAME FLYAWAY	15.917
PROPULSION FLYAWAY	6.003
AVIONICS FLYAWAY	6.850
OTHER FLYAWAY	3.000

OPERATIONS DATA:	
UE PER SQUADRON	18.0
UTIL RATE FHRS/UE/MONTH	33.3
CREW RATIO	2.0
PILOTS/CREW	2.0
OTHER OFFICERS/CREW	1.0
MAINTENANCE MAN HOURS/FHR	26.1
UNIT MAINT MEN/UE	10.0
FUEL FLOW GPH	1814.0
REPL SPARES $/FHR	510.0
BASE MAINT MTL $/FHR	308.0
DEPOT MAINT $/FHR	590.0
DEPOT MAINT $/UE/YR	76000.0
COMMON OSE $/UE/YR	61000.0

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ISADS STEALTH

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DESIGN INPUTS:	
TAKEOFF GROSS WEIGHT LBS.	302396.
EMPTY WEIGHT LBS.	79642.
AMPR WEIGHT LBS.	59839.
EQUIPMENT GROUP WEIGHT LBS.	26950.
INSTRUMENTS WEIGHT LBS.	855.
HYDRAULICS/PNEUMATICS LBS.	721.
ELECTRICAL GROUP WEIGHT LBS.	4305.
AVIONICS (INSTALLED) LBS.	9140.
SLS THRUST PER ENGINE LBS.	49895.
ENGINES PER AIRCRAFT	2.
MAXIMUM SPEED MACH	0.95
DYNAMIC PRESSURE LBS./SQ FT	1070.

PPE PERSONNEL/SQDN	OFFICERS	AIRMEN	CIVILIANS
AIRCREW	90		
MAINTENANCE	10	370	5
OVERHEAD	3	3	0
SECURITY	1	146	0
WING/BASE STAFF	30	37	1
PPE TOTAL	134	556	6
SPE PERSONNEL/SQDN			
BOS/RPM	3	84	18
MEDICAL	3	8	3
SPE TOTAL	6	92	21

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ISADS LASER D645-5 | RDT&E LABOR HOURS FOR 6 PROTOTYPE AIRCRAFTS | 03/16/78

WORK BREAKDOWN STRUCTURE	THOUSANDS OF HOURS ENG.	SHOP	TOOL.	MFGR.
TOTAL PROGRAM	15579.82	4307.96	10964.41	10498.77
AIR VEHICLE	6558.48	563.53	10964.41	6719.32
AIRFRAME	6558.48	563.53	9191.04	4387.71
BASIC STRUCTURE	1414.93	0.0	9191.04	4387.71
FUSELAGE	567.87	0.0	3938.98	1973.29
WING	455.59	0.0	2239.66	1048.21
EMPENNAGE	91.12	0.0	979.67	322.53
NACELLES	300.35	0.0	2083.13	1043.68
B.S. INTEG. ASSY.	0.0	0.0	0.0	0.0
LANDING GEAR	33.18	0.0	0.0	0.0
PROPULSION SYSTEM INSTALL	179.78	0.0	0.0	0.0
FUEL SYSTEM	752.79	0.0	0.0	0.0
ELECTRICAL SYSTEM	217.89	0.0	0.0	0.0
SECONDARY POWER	10.00	0.0	0.0	0.0
HYDRAULIC POWER	384.02	0.0	0.0	0.0
ENVIRONMENTAL CONTROL	511.14	0.0	0.0	0.0
CREW ACCOMMODATIONS	90.00	0.0	0.0	0.0
CONTROLS & DISPLAYS	176.54	0.0	0.0	0.0
FLIGHT CONTROLS	125.48	0.0	0.0	0.0
A/F INTEG. ASSY. INSTALL & CO	3202.69	563.53	0.0	0.0
ENGINEERING TECHNOLOGIES	2301.39	563.53	0.0	0.0
WEIGHT CONTROL	82.28	0.09	0.0	0.0
VIBRATION & FLUTTER	81.39	11.07	0.0	0.0
AERODYNAMICS	315.09	0.09	0.0	0.0
THERMODYNAMICS	1132.72	4.53	0.0	0.0
STRUCTURES	689.91	547.75	0.0	0.0
DESIGN SUPPORT TECHNOLOGIES	316.94	0.0	0.0	0.0
A/F ASSY. INSTALL & CO	584.36	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY. INSTALL	0.0	0.0	1373.37	2331.61

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AIRCRAFT/ITEMS LASER | RDT&E LABOR HOURS FOR 6 PROTOTYPE AIRCRAFTS | 03/16/78

WORK BREAKDOWN STRUCTURE	THOUSANDS OF HOURS ENG.	SHOP	TOOL.	MFGR.
TEST & EVALUATION	4399.58	3739.43	0.0	3700.68
WIND TUNNEL	490.71	8.61	0.0	0.0
FATIGUE ARTICLE TEST	424.48	1142.27	0.0	1906.82
STATIC ARTICLE TEST	599.73	943.49	0.0	1793.85
GROUND TEST	1986.90	606.56	0.0	0.0
MOCKUP & SIMULATORS	327.92	956.81	0.0	0.0
FLIGHT TEST	1276.28	389.49	0.0	0.0
TEST INTEGRATION, EVAL. & SUPPO	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	1137.24	0.0	0.0	0.0
SPARES & REPAIR PARTS	30.82	0.0	0.0	438.77
TRAINING	101.69	0.0	0.0	0.0
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	2861.46	0.0	0.0	0.0
DATA	260.34	0.0	0.0	0.0

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AIRCRAFT/ISADS LASER — RDT&E COST FOR 4 PROTOTYPE AIRCRAFTS — 03/16/78

ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TOTAL PROGRAM COST INCLUDE FEE								1700058.0
TOTAL PROGRAM COST INCLUDE G&A	344144.4	92727.9	262779.5	236914.1	61167.7	104995.8	25909.6	1611366.0
TOTAL PROG. INCL. MATL. BURDEN	324693.3	87479.2	229036.2	223903.7	57705.3	99052.6	24443.1	1548611.0
TOTAL PROGRAM COST LESS G&A	324689.3	87479.2	229036.2	223503.7	52459.4	90047.8	22220.9	1532138.0
AIR VEHICLE	134678.7	11456.7	229036.2	143991.8	2970.9	71521.9	22220.9	1120185.0
AIRFRAME	134678.7	11456.7	199261.6	93765.4	2970.9	71521.9	18622.7	534277.9
BASIC STRUCTURE	20487.1	0.0	199261.5	93765.4	0.0	22747.5	18622.7	363584.2
FUSELAGE	11834.8	0.0	85388.4	42169.3	0.0	3609.2	6749.3	149746.6
WING	9494.4	0.0	68555.7	22400.3	0.0	14206.2	5867.9	100524.4
EMPENNAGE	1898.0	0.0	20155.2	6892.6	0.0	1101.6	2435.7	32483.7
NACELLES	6259.3	0.0	45162.2	22303.5	0.0	3834.7	3569.7	81129.3
B.S. INTEG. ASSY.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LANDING GEAR	691.8	0.0	0.0	0.0	0.0	6879.3	0.0	7570.8
PROPULSION SYSTEM INSTALL	3746.5	0.0	0.0	0.0	0.0	0.0	0.0	3746.5
FUEL SYSTEM	5268.1	0.0	0.0	0.0	0.0	3319.7	0.0	8587.8
ELECTRICAL SYSTEM	4540.9	0.0	0.0	0.0	0.0	4914.4	0.0	9455.3
SECONDARY POWER	208.4	0.0	0.0	0.0	0.0	1861.1	0.0	2069.5
HYDRAULIC POWER	8002.9	0.0	0.0	0.0	0.0	1858.8	0.0	9861.8
ENVIRONMENTAL CONTROL	10652.2	0.0	0.0	0.0	0.0	12454.2	0.0	23106.4
CREW ACCOMMODATIONS	1042.0	0.0	0.0	0.0	0.0	2631.2	0.0	3673.2
CONTROLS & DISPLAYS	3680.2	0.0	0.0	0.0	0.0	4729.2	0.0	8409.4
FLIGHT CONTROLS	2615.0	0.0	0.0	0.0	0.0	10144.5	0.0	12759.3
A/F INTEG, ASSY, INSTALL & CO	66743.9	11456.7	0.0	0.0	2970.9	0.0	0.0	81171.5
ENGINEERING TECHNOLOGIES	47960.1	11456.7	0.0	0.0	2970.9	0.0	0.0	62387.6
WEIGHT CONTROL	1714.7	1.0	0.0	0.0	4.2	0.0	0.0	1719.9
VIBRATION & FLUTTER	1696.1	225.0	0.0	0.0	140.0	0.0	0.0	2061.2
AERODYNAMICS	6565.7	1.9	0.0	0.0	56.4	0.0	0.0	6624.0
THERMODYNAMICS	23605.8	92.1	0.0	0.0	688.7	0.0	0.0	24386.6
STRUCTURES	14377.8	11136.6	0.0	0.0	2081.6	0.0	0.0	27596.0
DESIGN SUPPORT TECHNOLOGIES	6605.9	0.0	0.0	0.0	0.0	0.0	0.0	6605.9
A/F ASSY, INSTALL & CO	12178.0	0.0	0.0	0.0	0.0	0.0	0.0	12178.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	292000.0
POWER PLANT (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	210708.3
A/V INTEGRATION, ASSY, INSTALL	0.0	0.0	29774.7	49926.4	0.0	0.0	3598.2	83199.2

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AIRCRAFT/ISADS LASER — RDT&E COST FOR 4 PROTOTYPE AIRCRAFTS — 03/16/78

ALL COST IN THOUSANDS AND 1977 DOLLARS

WORK BREAKDOWN STRUCTURE	LABOR				MATERIAL			
	ENG.	SHOP	TOOL.	MFGR.	ENG.	MFGR.	TOOL.	TOTAL
TEST & EVALUATION	91687.3	76022.6	0.0	70535.4	49488.4	11373.7	0.0	299107.4
WIND TUNNEL	8975.9	175.1	0.0	0.0	26217.7	0.0	0.0	35368.7
FATIGUE ARTICLE TEST	8865.1	23222.4	0.0	32200.8	1781.9	5686.9	0.0	71738.0
STATIC ARTICLE TEST	7371.8	17151.4	0.0	38334.6	1670.4	5686.9	0.0	70215.1
GROUND TEST	33062.6	8274.6	0.0	0.0	1322.9	0.0	0.0	42610.1
MOCKUP & SIMULATORS	6833.9	19413.4	0.0	0.0	12671.7	0.0	0.0	38919.0
FLIGHT TEST	26597.0	7835.7	0.0	0.0	5823.8	0.0	0.0	40256.5
TEST INTEGRATION, EVAL. & SUPPO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUPPORT EQUIPMENT	23700.1	0.0	0.0	0.0	0.0	0.0	0.0	23700.1
SPARES & REPAIR PARTS	642.4	0.0	0.0	9376.5	0.0	7152.2	0.0	17171.1
TRAINING	6287.2	0.0	0.0	0.0	0.0	0.0	0.0	6287.2
ASSOC. SYS. MODIFICATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INDUSTRIAL FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYS. ENGR. & PROGRAM MGMT.	59632.9	0.0	0.0	0.0	0.0	0.0	0.0	59632.9
DATA	6094.9	0.0	0.0	0.0	0.0	0.0	0.0	6094.9

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AIRCRAFT: ISADS LASER — PRODUCTION COST FOR 200 UNITS — 03/16/78

ALL COSTS IN MILLIONS AND IN 1977 DOLLARS. — UNIT AVG. FLYAWAY COST 34.723

WORK BREAKDOWN STRUCTURE	LABOR COST MFG.	LABOR COST TOOL.	LABOR COST PLNG.	LABOR COST ENGR.	LABOR COST QERA	MATERIAL COST MFG.	MATERIAL COST TOOL.	TOTAL COST
TOTAL PROGRAM COST INCLUDING FEE	1936.30	485.97	179.56	194.97	278.61	1163.82	53.26	6944.64
TOTAL PROGRAM COST INCLUDING G&A	1760.27	441.79	163.24	177.25	253.29	1058.02	48.42	6554.41
TOTAL PROGRAM COST LESS G&A	1550.53	415.79	154.00	167.21	239.94	998.13	45.68	6333.54
AIR VEHICLE	1560.63	416.79	154.00	167.21	238.94	998.13	45.68	6333.54
AIRFRAME	1153.71	371.35	116.12	167.21	175.30	998.13	40.70	3022.52
BASIC STRUCTURE	816.29	371.35	83.29	30.05	136.38	264.89	40.70	1742.96
FUSELAGE	219.74	155.39	26.50	12.60	43.01	40.96	17.03	514.71
WING	354.22	88.36	31.02	10.18	50.91	154.75	9.68	699.11
EMPENNAGE	25.35	36.68	4.26	0.48	7.09	12.04	4.02	89.91
NACELLES	119.48	82.18	14.24	6.71	23.12	57.75	9.01	312.45
BASIC STRUCTURE ASSEMBLY	97.56	0.74	7.29	0.0	12.24	0.0	0.96	126.77
LANDING GEAR	0.0	0.0	0.0	1.11	0.0	94.03	0.0	95.14
FUEL SYSTEM	17.00	0.0	1.56	5.65	1.96	10.32	0.0	36.49
FLIGHT VEHICLE POWER	222.13	0.0	16.21	13.67	25.62	179.67	0.0	457.30
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	11.42	0.0	200.80	0.0	212.21
CREW ACCOMMODATIONS	47.77	0.0	3.52	3.35	5.51	0.0	0.0	60.15
CONTROLS AND DISPLAYS	0.0	0.0	0.0	11.33	0.0	55.56	0.0	66.88
FLIGHT CONTROLS	50.52	0.0	3.67	2.90	5.83	157.68	0.0	220.49
ARMAMENT	0.0	0.0	0.0	0.67	0.0	35.21	0.0	35.88
AIR INDUCTION CONTROL SYSTEM	0.0	0.0	0.0	16.80	0.0	0.0	0.0	16.80
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	70.36	0.0	0.0	0.0	70.36
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	44.37	0.0	0.0	0.0	44.37
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	9.14	0.0	0.0	0.0	9.14
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	16.85	0.0	0.0	0.0	16.85
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1282.15
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1370.00
A/V INTEGRATION, ASSY, INSTALL	506.93	45.44	37.88	0.0	63.64	0.0	4.98	658.87

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AIRCRAFT: ISADS LASER — 03/16/78

AIRCRAFT WEIGHTS - IN POUNDS

	AL	TI	ST	BO	GR	EG	SA	TOTAL
FUSELAGE	7366.	965.	143.	0.	2682.	95.	0.	11919.
FRAME/LONG	7366.	965.	143.	0.	1204.	0.	0.	9678.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	0.	0.	0.	0.	1478.	95.	0.	1573.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		0.						0.
MISC								667.
WING	0.	1778.	334.	0.	17607.	647.	0.	20886.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	0.	1298.	334.	0.	14808.	0.	0.	16437.
BOND HONEY	0.	0.	0.	0.	2799.	647.	0.	3446.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		480.						480.
MISC								522.
EMPENNAGE	0.	242.	0.	0.	1278.	0.	0.	1585.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
MULTI-SPAR	0.	6.	0.	0.	842.	0.	0.	848.
BOND HONEY	0.	0.	0.	0.	436.	0.	0.	436.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
MISC								46.
SUPERPLASTIC		255.						295.
NACELLE	0.	4905.	177.	0.	1034.	0.	0.	6304.
FRAME/LONG	0.	0.	177.	0.	1034.	0.	0.	1210.
SKIN-STRGR	0.	0.	0.	0.	0.	0.	0.	0.
BOND HONEY	0.	0.	0.	0.	0.	0.	0.	0.
BRAZE HONEY		0.	0.				0.	0.
DIFF BOND		0.					0.	0.
SUPERPLASTIC		4905.						4905.
MISC								189.

WEIGHT DATA - IN POUNDS	
AMPR WEIGHT	82393.
STRUCTURE WT	51043.
STRUCTURAL HOWF WT	0.
SYSTEM HOWF WT	0.
LANDING GEAR WT	9999.
FUEL SYSTEM WT	2139.
ELECTRICAL SYSTEM WT	5688.
HYDRAULIC SYSTEM WT	1139.
AUX POWER SYSTEM WT	311.
ECS WT	5105.
CREW ACCOM WT	2990.
CONTROL & DISPLAY WT	955.
FLIGHT CONTROL WT	2921.
ARMAMENT WT	1169.
AICS MECHANISM WT	0.
EQUIPMENT WT	33472.
ENGINE WT	12779.
EMPTY WT	109108.
FUEL WT	169718.
TOGW	340098.

[illegible]	
[illegible]	3358.
[illegible]A-SQ FT	234.
[illegible] FT	9679.
[illegible]AREA	3358.
[illegible]	116.0
[illegible]	0.0
Q[illegible] FT	104.0
ASP[illegible]	4.00
DYNA[illegible]RE	1070.
MAX V[illegible]	0.95
ENGINES PER A/C	4.
A/C THRUST - LBS	110420.
MAX GEES	5.00

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AIRCRAFT: SADS LASER
PRODUCTION HOURS DATA FOR 200 UNITS 03/16/78

PRODUCTION MAN-HOURS IN MILLIONS

WORK BREAKDOWN STRUCTURE	MFG.	TOOL.	PLNG.	ENGR.	QERA.	TOTAL
TOTAL PROGRAM HOURS	77.709	19.225	7.414	8.024	11.346	123.717
AIR VEHICLE	77.709	19.225	7.414	8.024	11.346	123.717
AIRFRAME	53.987	17.129	5.591	5.074	8.324	93.094
BASIC STRUCTURE	35.198	17.129	4.010	1.442	6.476	57.255
FUSELAGE	10.283	7.167	1.276	0.609	2.042	21.377
WING	14.575	6.076	1.493	0.488	2.417	25.050
EMPENNAGE	1.186	1.492	0.205	0.023	0.337	3.443
NACELLES	5.990	3.791	0.695	0.322	1.098	11.486
BASIC STRUCTURE ASSEMBLY	6.566	0.609	0.151	0.0	0.581	5.900
LANDING GEAR	0.0	0.0	0.0	0.093	0.0	0.093
FUEL SYSTEM	0.706	0.0	0.075	0.271	0.093	1.235
FLIGHT VEHICLE POWER	10.304	0.0	0.781	0.656	1.217	13.067
ENVIRONMENTAL CONTROL	0.0	0.0	0.0	0.568	0.0	0.568
CREW ACCOMMODATIONS	2.255	0.0	0.149	0.141	0.262	2.827
CONTROLS AND DISPLAYS	0.0	0.0	0.0	0.544	0.0	0.544
FLIGHT CONTROLS	2.364	0.0	0.176	0.134	0.277	2.952
ARMAMENT	0.0	0.0	0.0	0.032	0.0	0.032
AIR INDUCTION CONTROL SYSTEM	0.0	0.0	0.0	0.806	0.0	0.806
AIRFRAME INTEGRATION & CHECK	0.0	0.0	0.0	3.376	0.0	3.376
ENGINEERING TECHNOLOGIES	0.0	0.0	0.0	2.129	0.0	2.129
DESIGN SUPPORT TECHNOLOGIES	0.0	0.0	0.0	0.439	0.0	0.439
AIRFRAME INSTALL & CHECKOUT	0.0	0.0	0.0	0.809	0.0	0.809
PROPULSION (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
AVIONICS (GFE)	0.0	0.0	0.0	0.0	0.0	0.0
A/V INTEGRATION, ASSY, INSTALL	21.722	2.096	1.824	0.0	3.032	30.663

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AIRCRAFT: SADS LASER
COSTS IN THOUSANDS AND IN 1977 DOLLARS - NO MPC

MATERIAL/PROCESS	FUSL.	WING	EMP.	NAC.	MORT.
ALUMINUM:					
SKIN	0.	0.	0.	0.	1.067
SHEET	2437.	0.	0.	0.	1.047
PLATE	0.	0.	0.	0.	1.067
EXTRUSION	1799.	0.	0.	0.	1.077
FORGING	5862.	0.	0.	0.	1.079
CORE	2143.	6057.	632.	0.	1.115
TITANIUM:					
SKIN	0.	4993.	752.	14176.	1.132
SHEET	9919.	8182.	1980.	20844.	1.132
PLATE	0.	1693.	9.	0.	1.137
EXTRUSION	2206.	1679.	7.	0.	1.137
FORGING	2108.	1613.	7.	0.	1.137
DIFF BOND	0.	0.	0.	0.	1.039
CORE	0.	0.	0.	0.	1.115
STEEL:	511.	1194.	0.	531.	1.047
BORON:	0.	0.	0.	0.	1.112
GRAPHITE:	15130.	113939.	7751.	5088.	1.112
FIBERGLASS:					
SHEET	319.	2134.	0.	0.	1.067
CORE	74.	900.	0.	0.	1.115
SUPER ALLOYS:					
SKIN	0.	0.	0.	0.	1.132
SHEET	0.	0.	0.	0.	1.132
PLATE	0.	0.	0.	0.	1.132
EXTRUSION	0.	0.	0.	0.	1.132
FORGING	0.	0.	0.	0.	1.079
DIFF BOND	0.	0.	0.	0.	1.095
CORE	0.	0.	0.	0.	1.115
MISCELLANEOUS:	19.	2317.	204.	839.	1.096

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RAW MATERIAL COST FOR 200 AIRCRAFT

OTHER INPUT DATA:

NORMAL FORCE ON AERO SURFACES	9.00
MAXIMUM MACH NUMBER	0.95
LANDING SINK RATE-FT/SEC	10.0
ENGINES PER AIRCRAFT	4.
TOTAL SLS THRUST/ENG - LBS	27605.
TOTAL THRUST/ACFT -LBS	110420.
INITIAL PRODN RATE-ACFT/MO	2.
FINAL PRODN RATE-ACFT/MO	4.
YEAR PRODN COMMENCES	1989.
NUMBER OF CREW PER ACFT	3.
FLEXIBILITY COEFFICIENT	1.55

RATE DATA:

MANUFACTURING LABOR & BURDEN	21.37
TOOLING LABOR & BURDEN	21.68
PLANNING LABOR & BURDEN	20.77
ENGINEERING LABOR & BURDEN	20.84
QERA LABOR & BURDEN	21.06
MFG QERA	21.06
TOOLING QERA	21.06
MPC - PERCENT	10.00
GSA - PERCENT	6.00
FEE - PERCENT	10.00

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TRADS LASER
COSTS IN FY 1977 MILLION DOLLARS

LIFE CYCLE COST	18766.77
RDT&E	3146.72
AIRFRAME	1197.35
PROPULSION	210.71
AVIONICS	403.66
OTHER	1335.00
ACQUISITION	9630.19
PRODUCTION	9194.96
FLYAWAY	8068.39
INITIAL SPARES	678.00
INITIAL OSE	254.93
TRAINING EQUIPMENT	104.89
TECHNICAL DATA	88.75
OTHER INVESTMENT	435.23
TRANSPORTATION	183.90
INITIAL PERSONNEL ACQUISITION	101.80
INITIAL PERSONNEL TRAINING	149.53
FACILITIES	0.0
TOTAL OPERATIONS FOR 15 YEARS	5989.86
RECURRING INVESTMENT & MISC. LOGISTICS	3591.32
COMMON OSE	270.37
AVIATION FUEL	849.99
BASE LEVEL MAINTENANCE MATERIAL	323.37
BASE LEVEL MAINTENANCE	981.68
DEPOT LEVEL MAINTENANCE	475.90
CLASS IV MODIFICATIONS	0.06
TRAINING MUNITIONS	682.43
REPLENISHMENT SPARES	7.51
VEHICULAR EQUIPMENT	
PAY AND ALLOWANCES	1908.85
MED. BOS/RPM SUPPORT	33.34
MEDICAL SUPPORT	80.25
PERSONNEL SUPPORT (PCS MOVES)	65.63
PERSONNEL ACQUISITION AND TRAINING	310.47

TOTAL PRODUCTION AIRCRAFT	200
TOTAL UE	175
COMMAND SUPPORT	12
ATTRITION	13
TOTAL PROTOTYPE AIRCRAFT	4

UNIT AVERAGE FLYAWAY COST	40.342
AIRFRAME FLYAWAY	21.462
PROPULSION FLYAWAY	6.411
AVIONICS FLYAWAY	9.469
OTHER FLYAWAY	3.000

OPERATIONS DATA:

UE PER SQUADRON	15.0
UTIL RATE FHRS/UE/MONTH	33.3
CREW RATIO	2.0
PILOTS/CREW	2.0
OTHER OFFICERS/CREW	2.0
MAINTENANCE MAN HOURS/FHR	21.2
MUNIT MAINT MEN/UE	10.0
FUEL FLOW GPH	1840.0
REPL SPARES $/FHR	650.0
BASE MAINT MTL $/FHR	308.0
DEPOT MAINT $/FHR	680.0
DEPOT MAINT $/UE/YR	102000.0
COMMON OSE $/UE/YR	103000.0

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TRADS LASER

DESIGN INPUTS:

TAKEOFF GROSS WEIGHT LBS.	340808.
EMPTY WEIGHT LBS.	109108.
DCPR WEIGHT LBS.	82393.
EQUIPMENT GROUP WEIGHT LBS.	33460.
INSTRUMENTS WEIGHT LBS.	955.
HYDRAULICS/PNEUMATICS LBS.	1139.
ELECTRICAL GROUP WEIGHT LBS.	9688.
AVIONICS (INSTALLED) LBS.	12635.
SLS THRUST PER ENGINE LBS.	27605.
ENGINES PER AIRCRAFT	4.
MAXIMUM SPEED MACH	0.95
DYNAMIC PRESSURE LBS./SQ FT	1070.

PPE PERSONNEL/SQDN	OFFICERS	AIRMEN	CIVILIANS
AIRCREW	120	388	5
MAINTENANCE	11	3	0
OVERHEAD	3	146	0
SECURITY	1	37	1
WING/BASE STAFF	30	574	6
PPE TOTAL	165		

SPE PERSONNEL/SQDN	OFFICERS	AIRMEN	CIVILIANS
BOS/RPM	3	89	19
MEDICAL	3	8	3
SPE TOTAL	6	97	22

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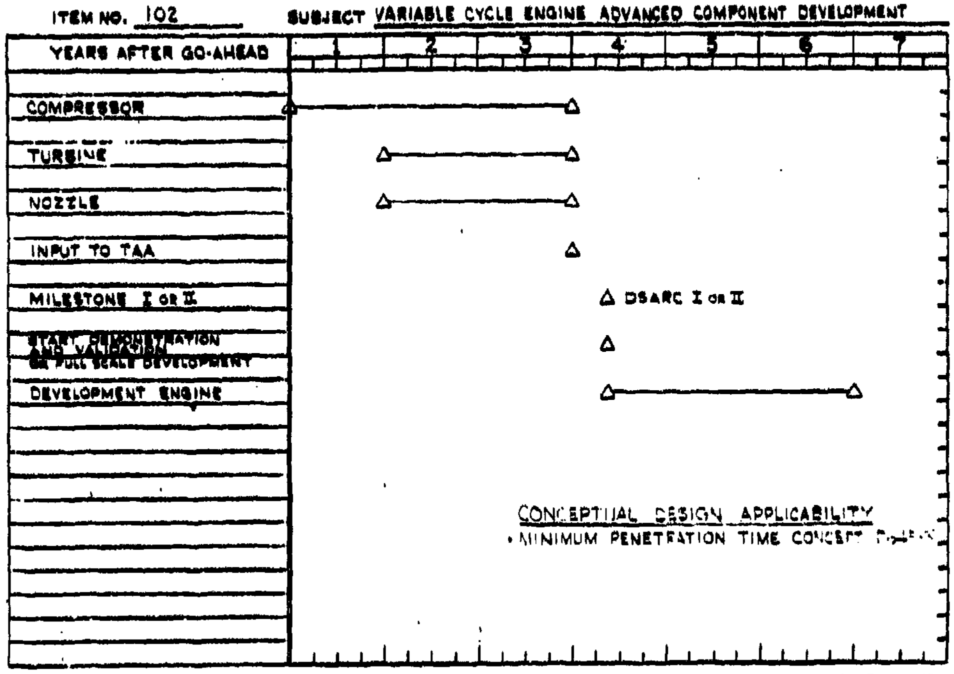
Appendix G

TECHNOLOGY SCHEDULES

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

ITEM NO. 102 SUBJECT VARIABLE CYCLE ENGINE ADVANCED COMPONENT DEVELOPMENT



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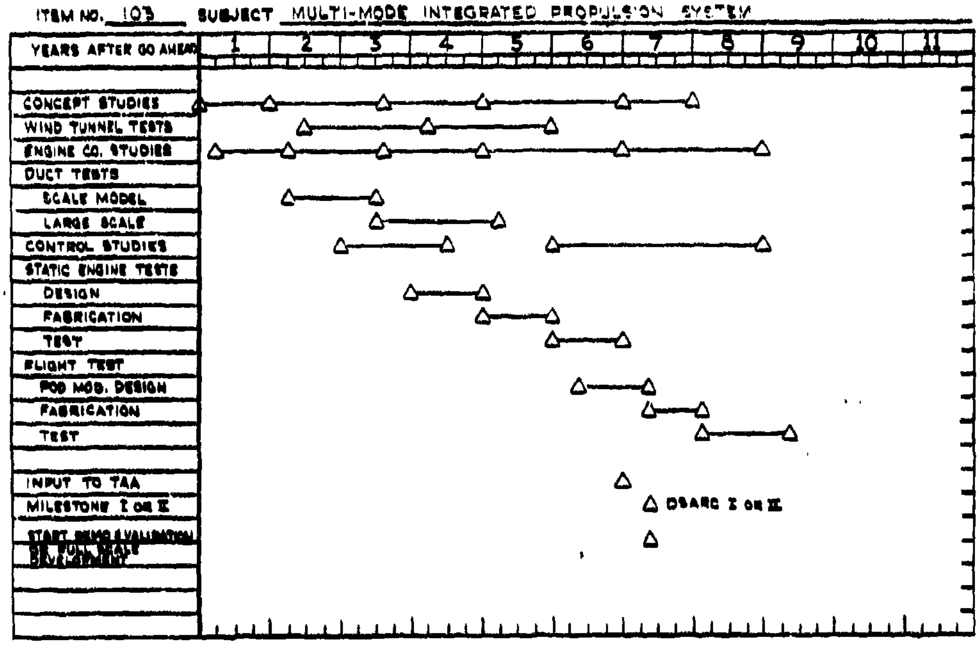
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

ITEM NO. 103 SUBJECT MULTI-MODE INTEGRATED PROPULSION SYSTEM



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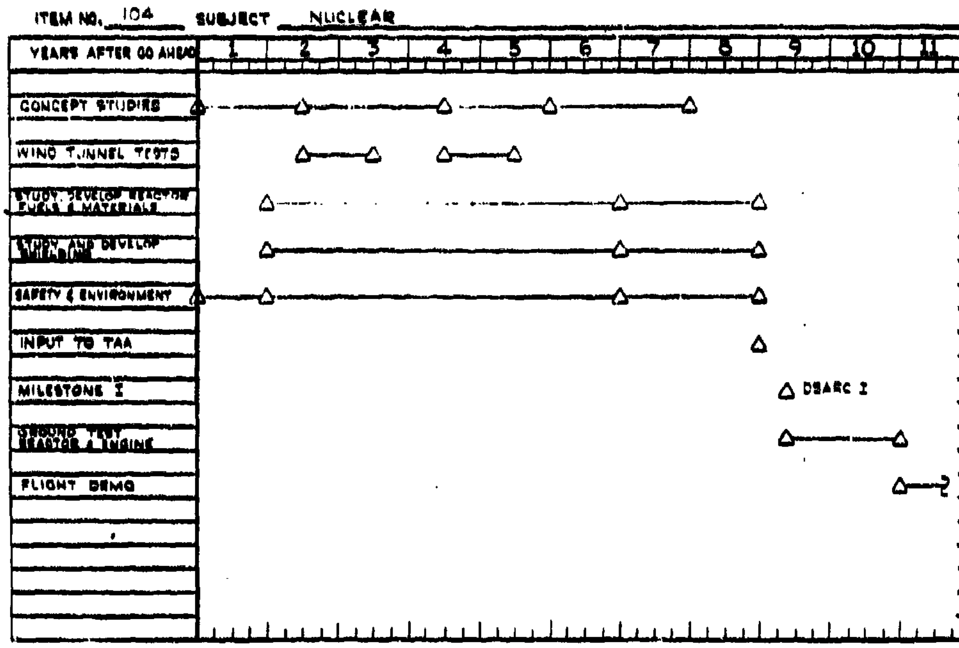
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)



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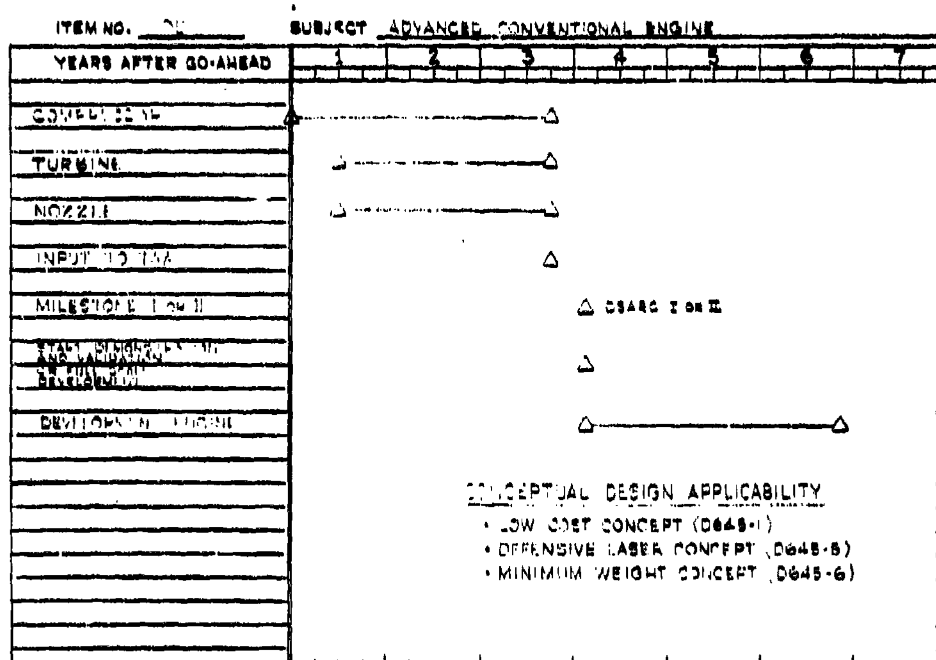
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)



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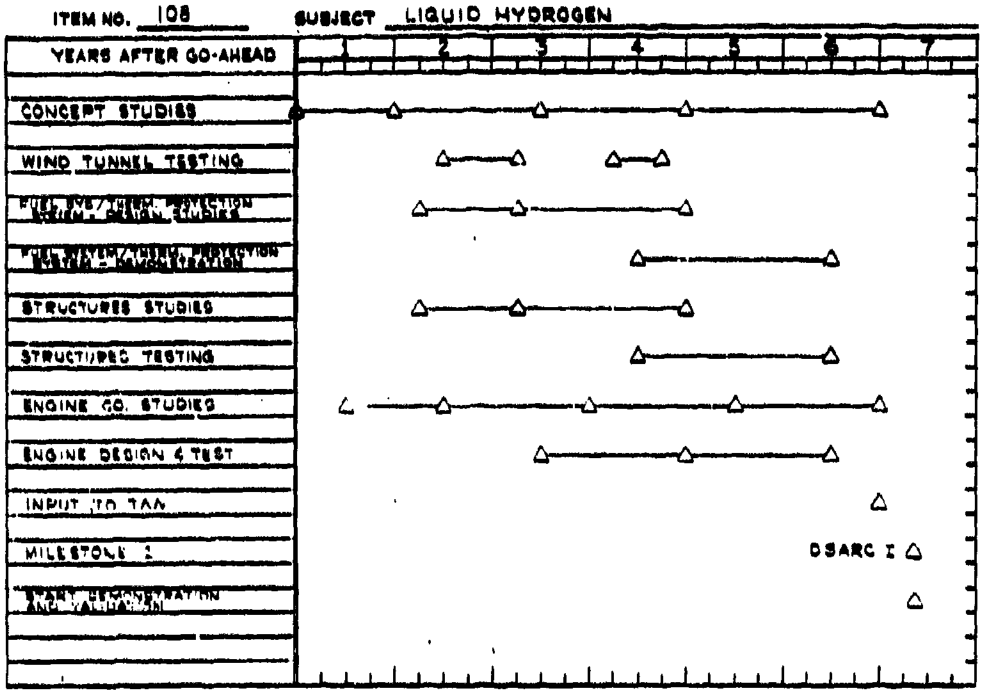
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)



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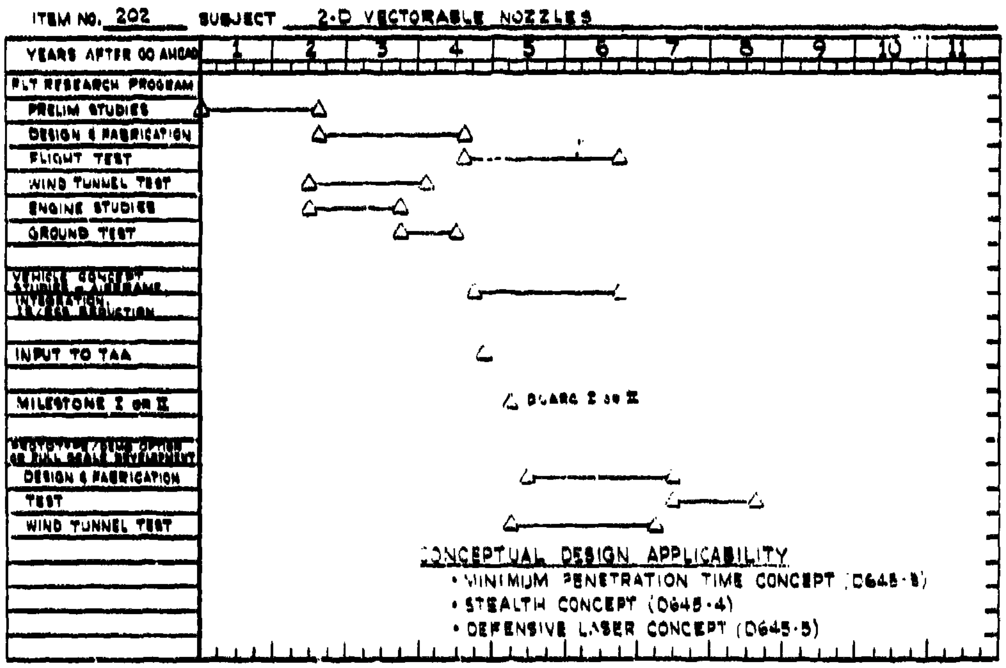
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)



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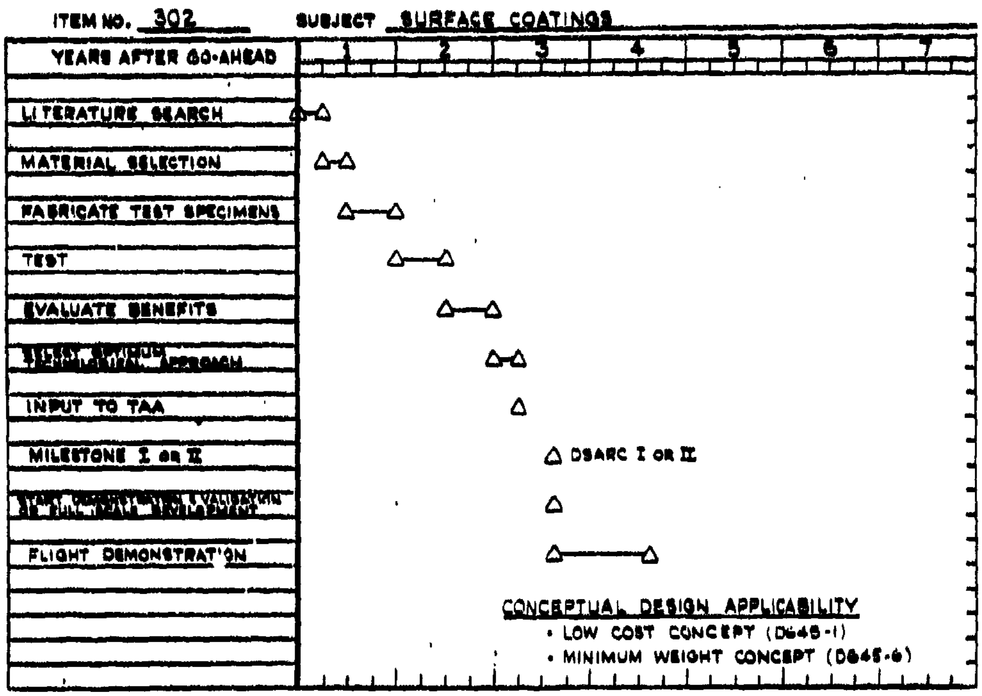
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)



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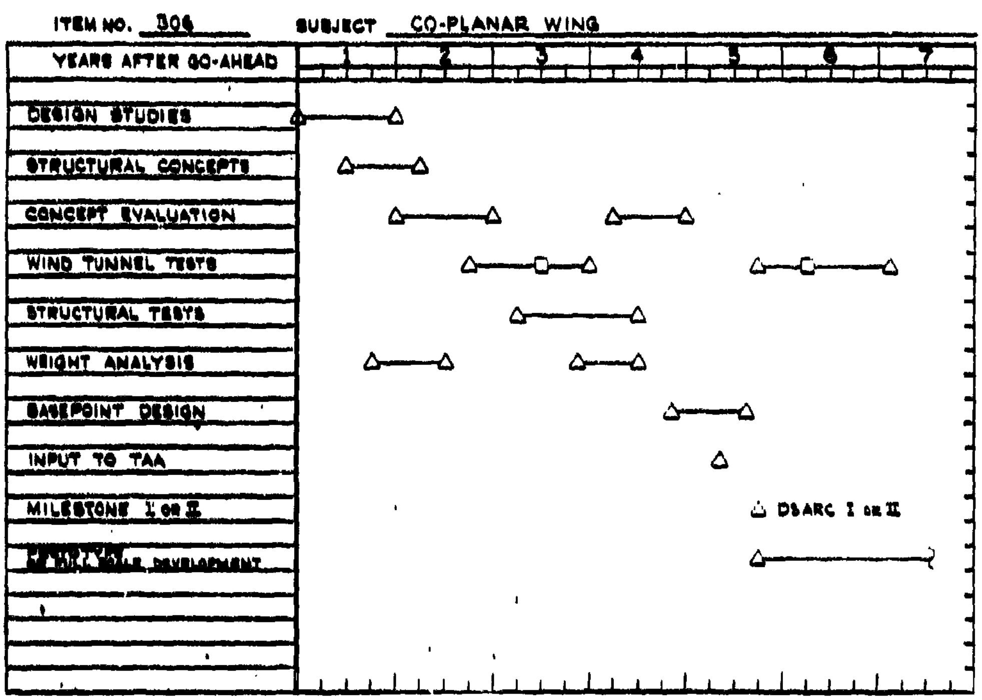
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)



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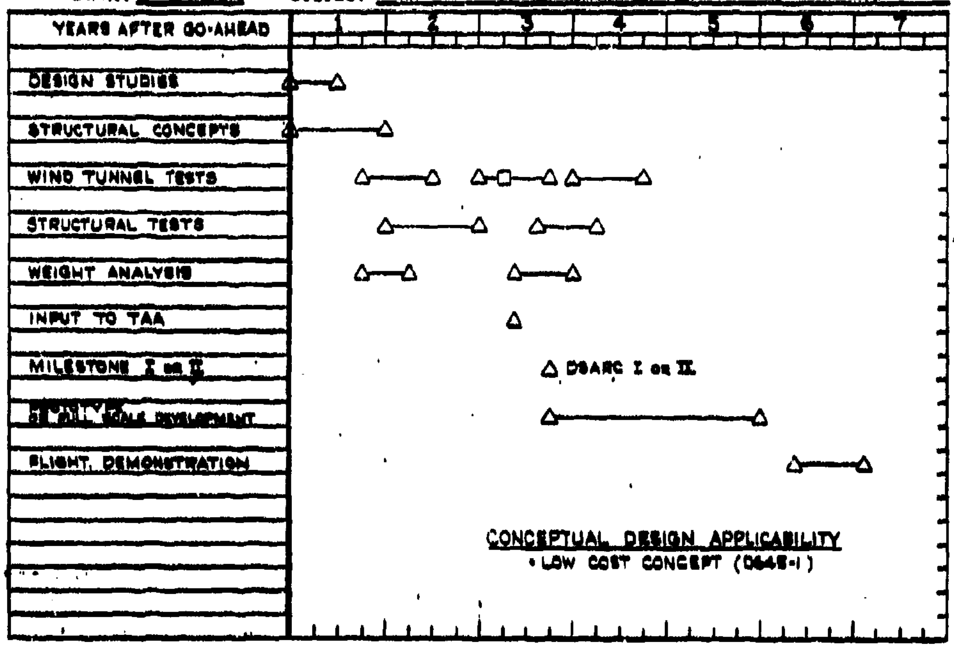
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

ITEM NO. 308 SUBJECT FORWARD WING SWEEP



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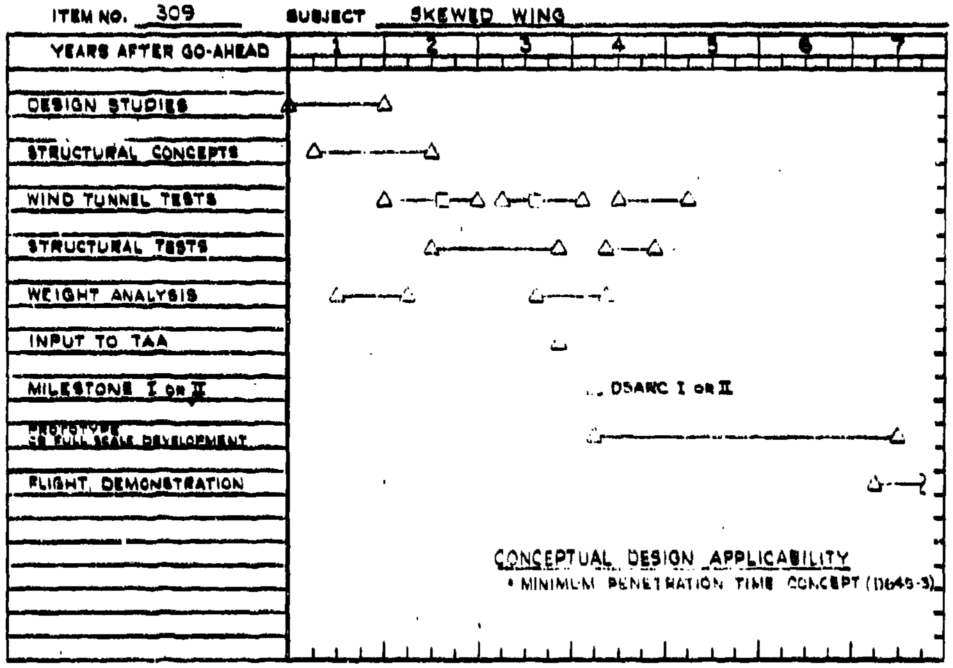
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

ITEM NO. 309 SUBJECT SKEWED WING



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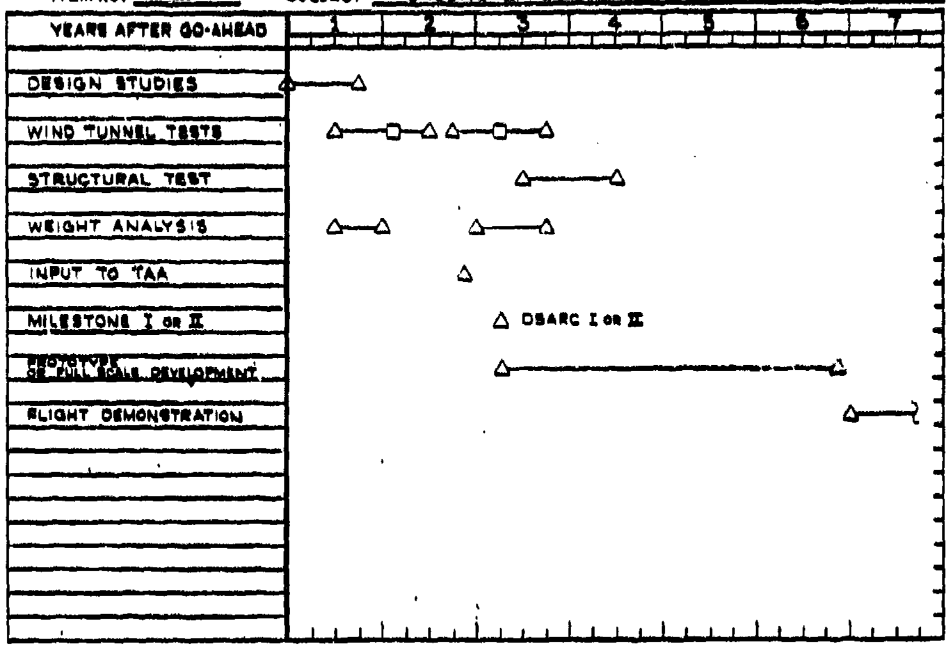
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

ITEM NO. 311 SUBJECT GROUND EFFECT



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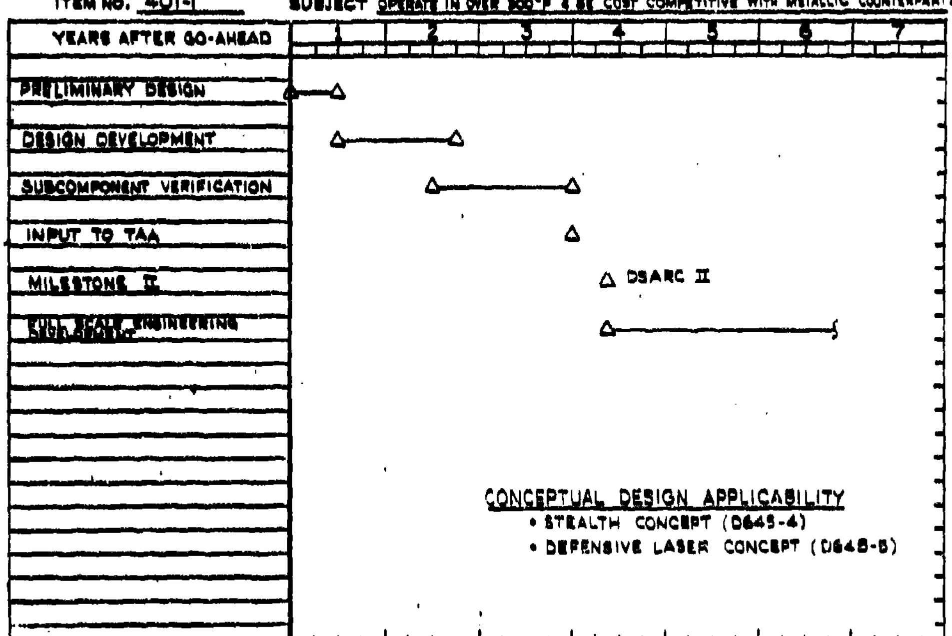
(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

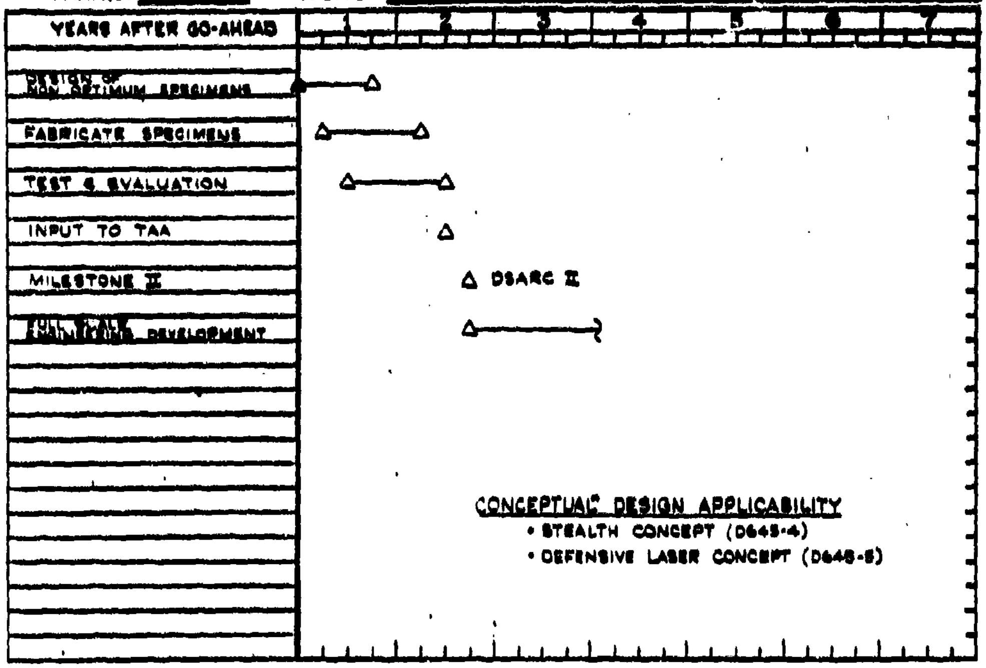
ITEM NO. 401-1 SUBJECT ADVANCED COMPOSITES - DEMONSTRATE COMPOSITE COMPONENTS TO OPERATE IN OVER 800°F & BE COST COMPETITIVE WITH METALLIC COUNTERPARTS



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

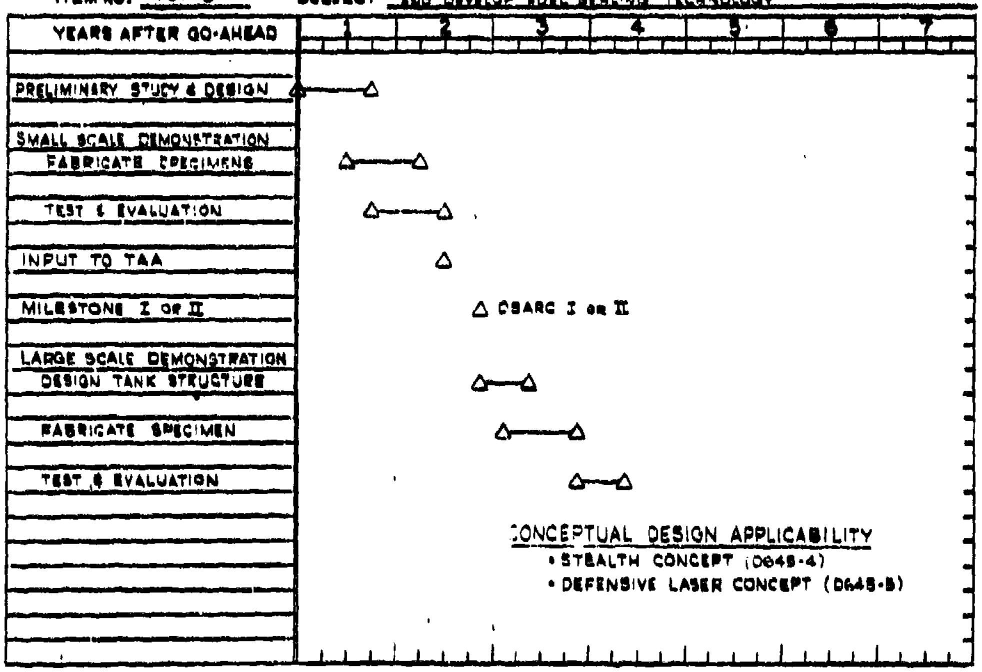
ITEM NO. 401-2 SUBJECT ADVANCED COMPOSITES - [illegible]



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

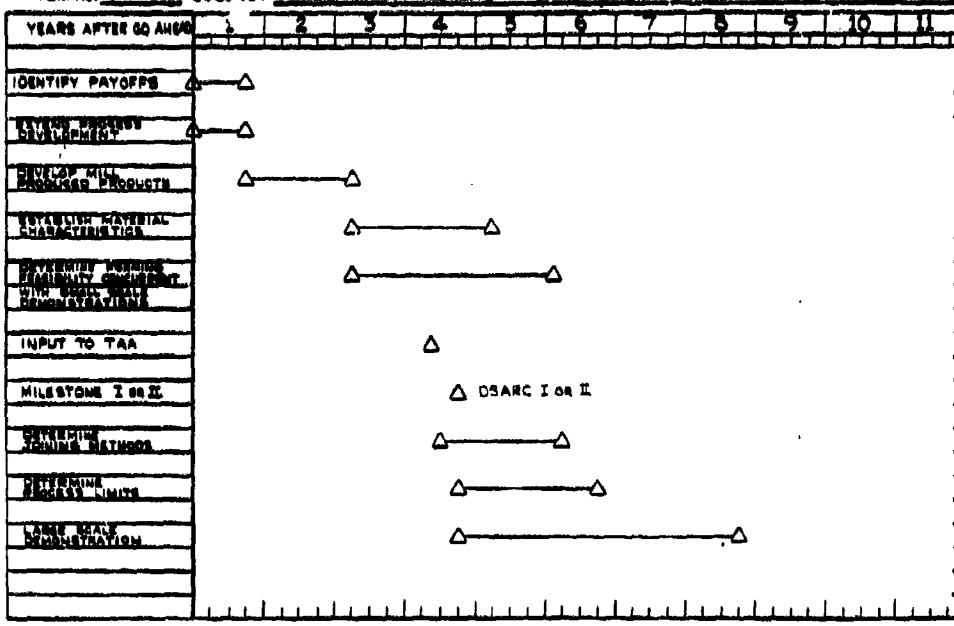
ITEM NO. 401-3 SUBJECT ADVANCED COMPOSITES - DETERMINE EFFECT OF EMERGING FUELS AND DEVELOP FUEL SEALING TECHNOLOGY



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

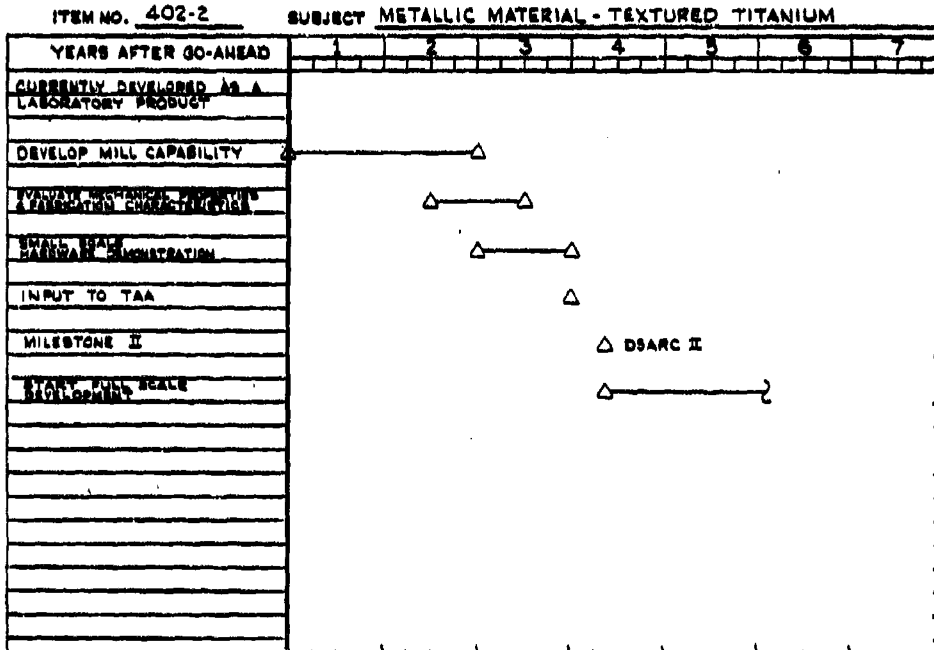
ITEM NO. 402-1 SUBJECT METALLIC MATERIAL - HIGH STRENGTH ALUMINUM



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

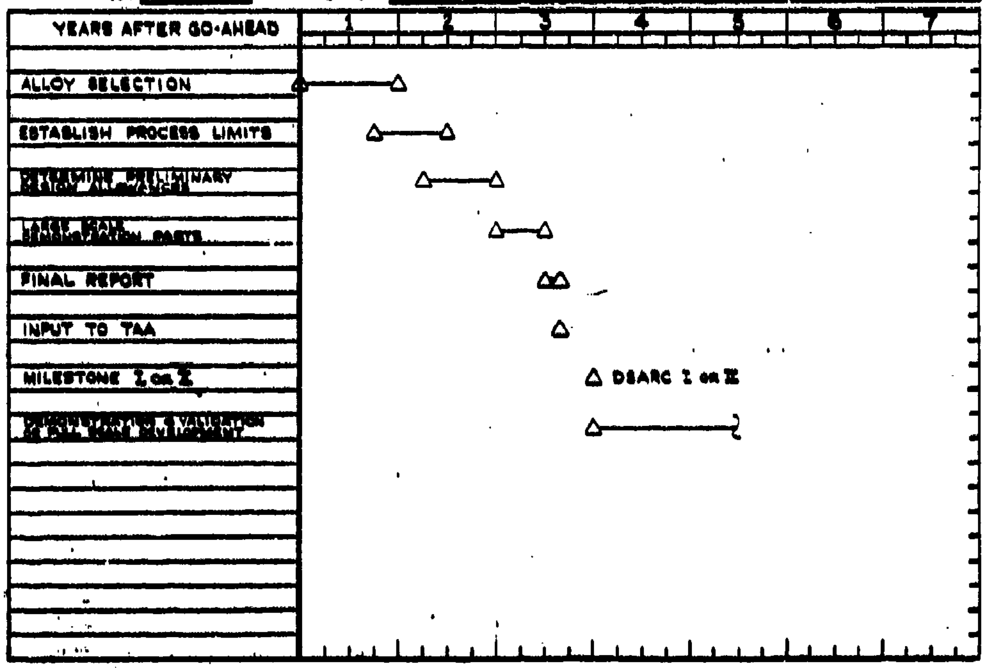
ITEM NO. 402-2 SUBJECT METALLIC MATERIAL - TEXTURED TITANIUM



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

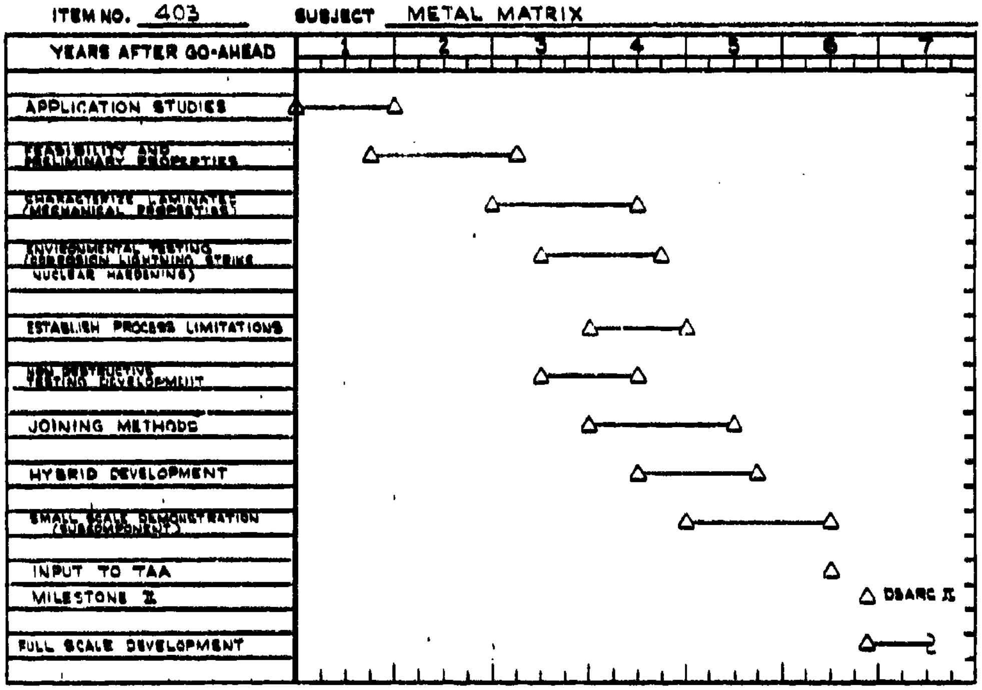
ITEM NO. 402-3 SUBJECT METALLIC MATERIAL - DEVELOP FABRICATION CAPABILITY FOR ARC SEAM WELDING OF ALUMINUM



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

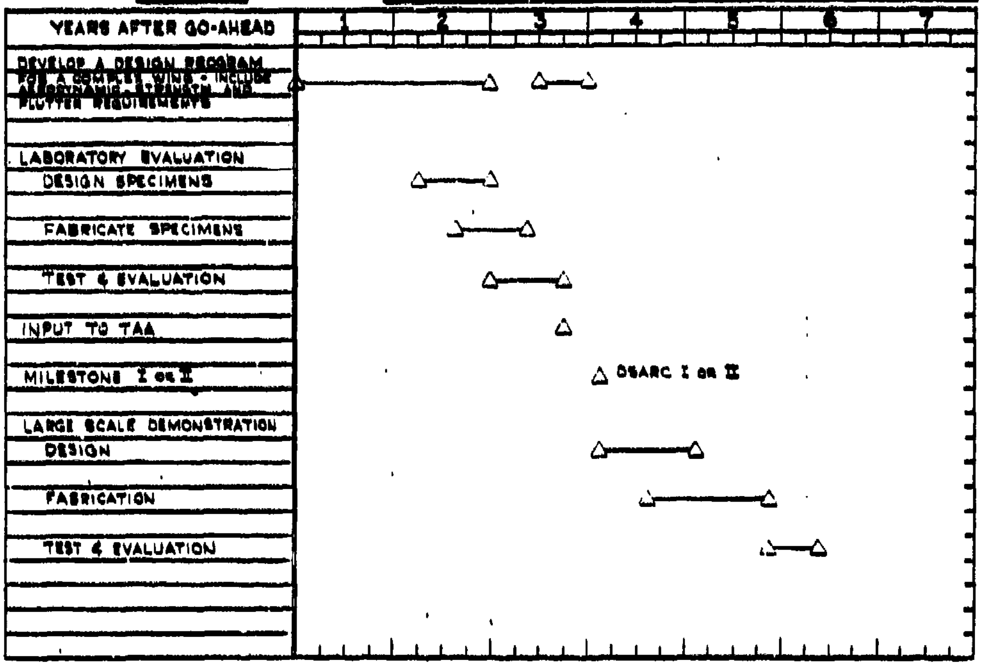
ITEM NO. 403 SUBJECT METAL MATRIX



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

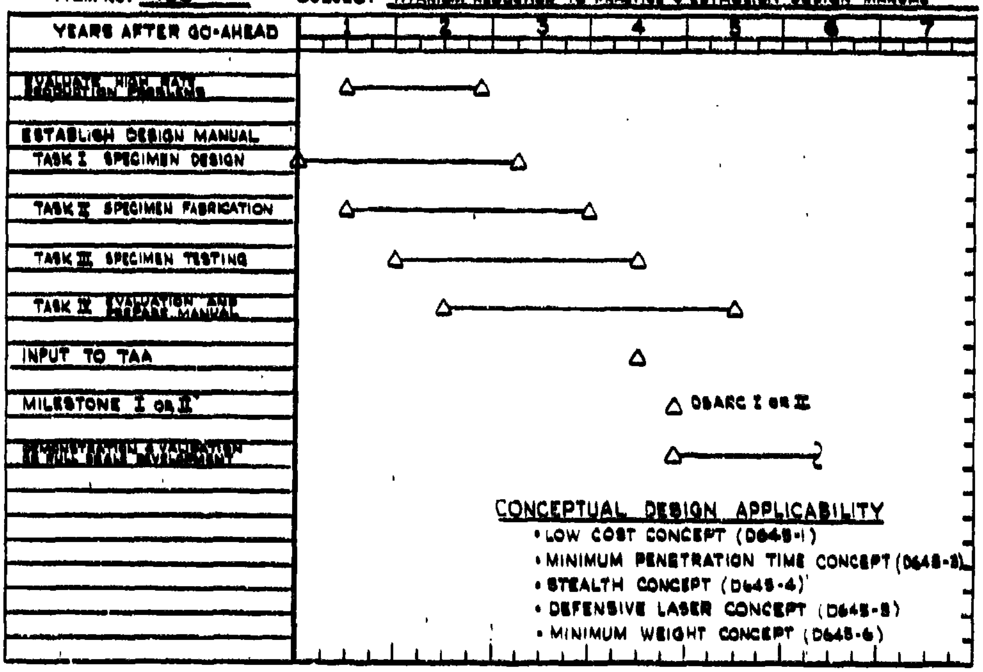
ITEM NO. 404 SUBJECT AEROELASTIC TAILORING - IMPROVE DESIGN OPTIMIZATION



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

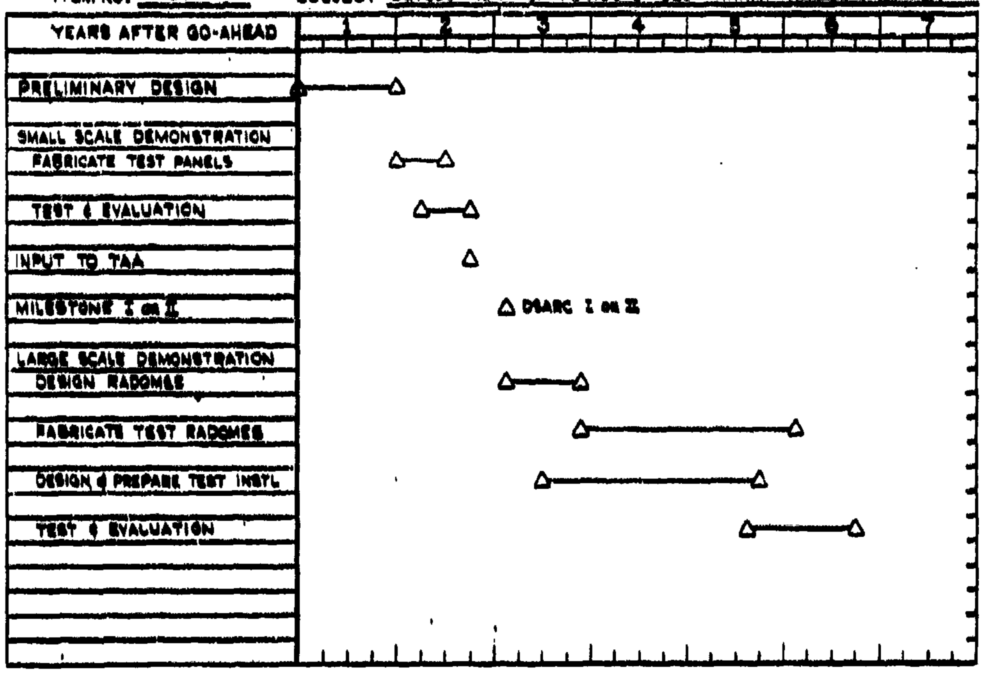
ITEM NO. 406 SUBJECT SUPERPLASTIC FORMING / DIFFUSION BONDING - TITANIUM REDUCTION TO PRACTICE & ESTABLISH DESIGN MANUAL



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

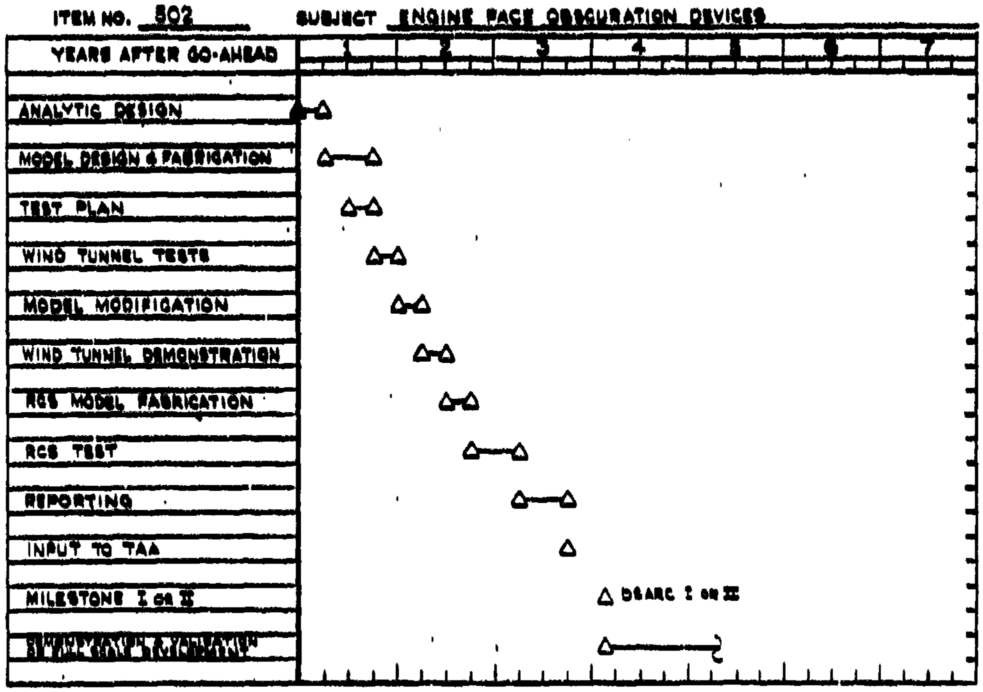
ITEM NO. 407 SUBJECT DEVELOPMENT OF PERIODIC SLOT ARRAY RADOME



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

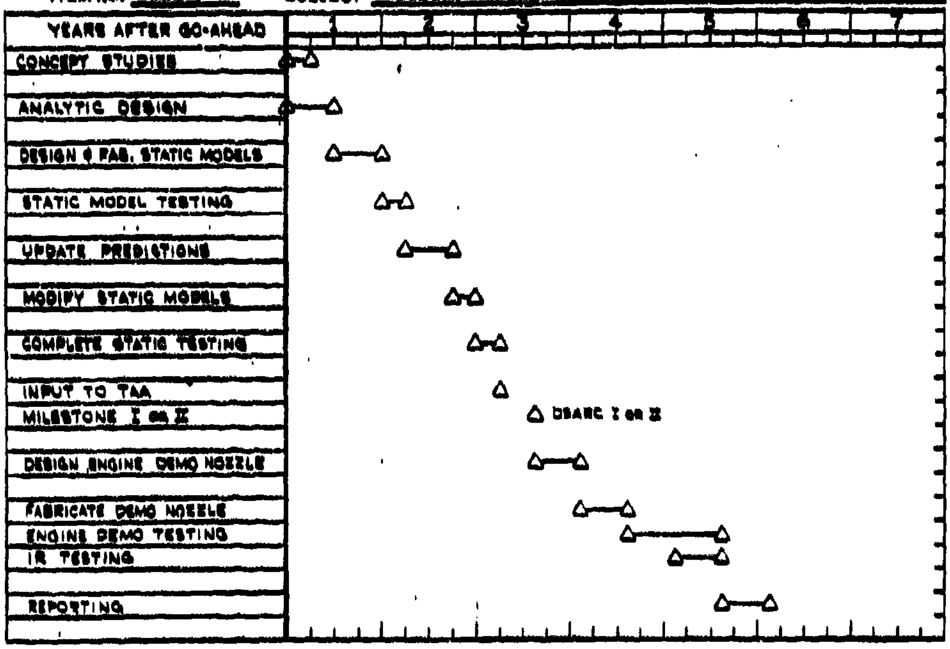
ITEM NO. 502 SUBJECT ENGINE FACE OBSCURATION DEVICES



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

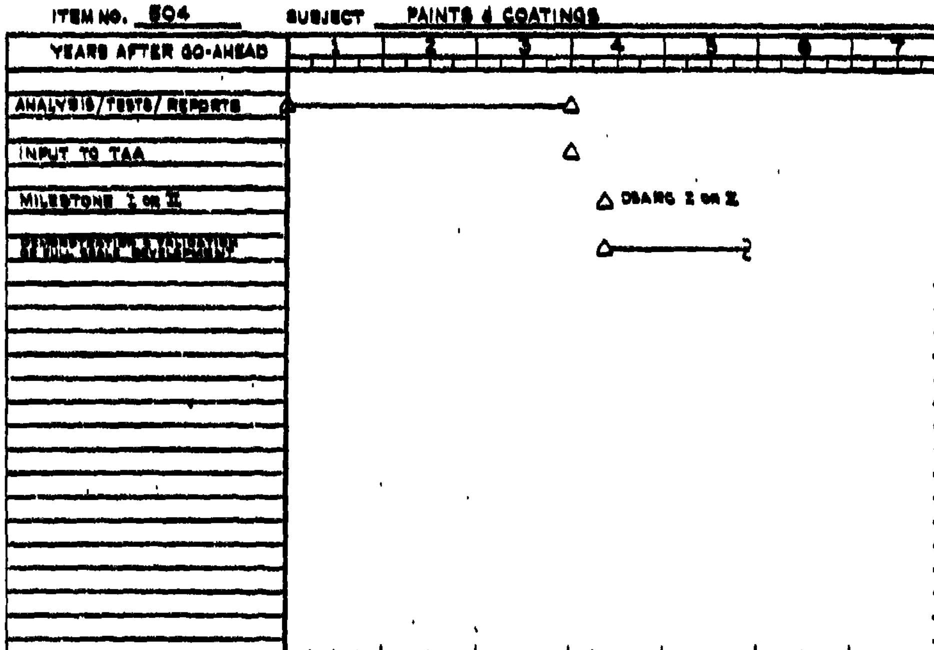
ITEM NO. 503   SUBJECT COOLED PLUG NOZZLES



UNCLASSIFIED

(U) ISADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

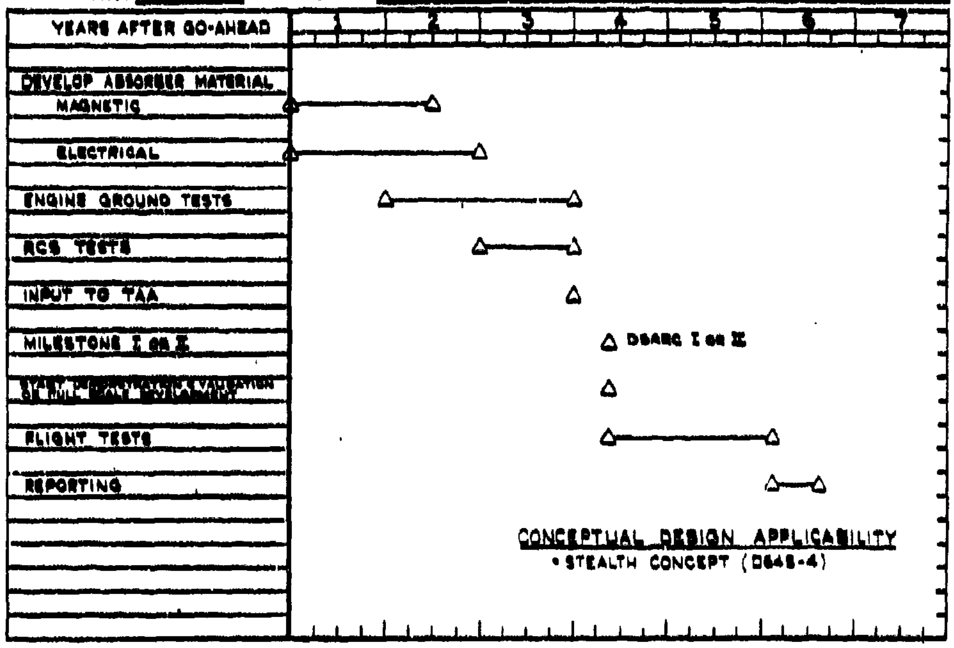
ITEM NO. 504   SUBJECT PAINTS & COATINGS



UNCLASSIFIED

(U) I3ADS ADVANCE TECHNOLOGY LEAD-IN PROGRAM SCHEDULE (U)

ITEM NO. 508 SUBJECT RAM (HIGH TEMPERATURE)

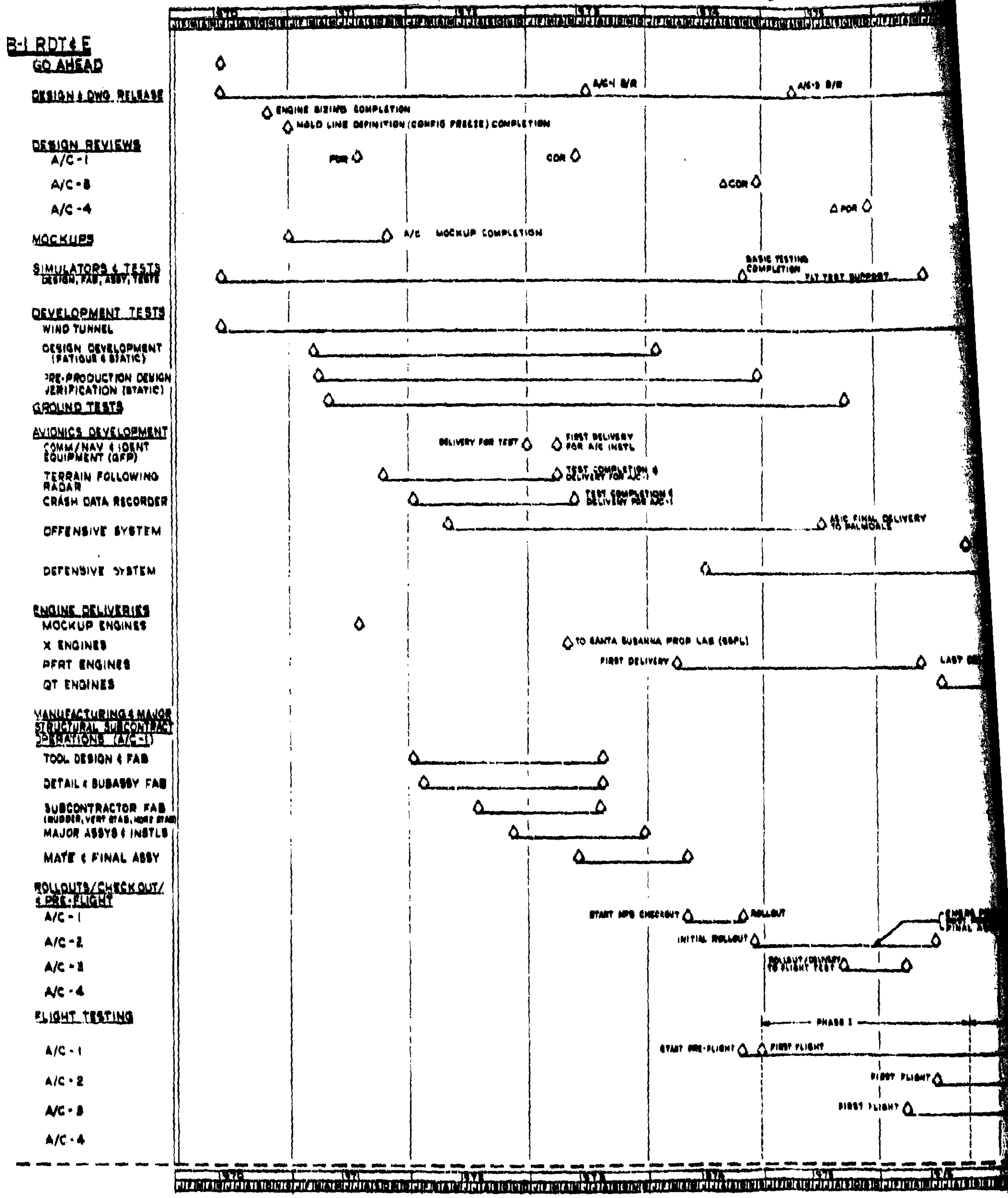


UNCLASSIFIED

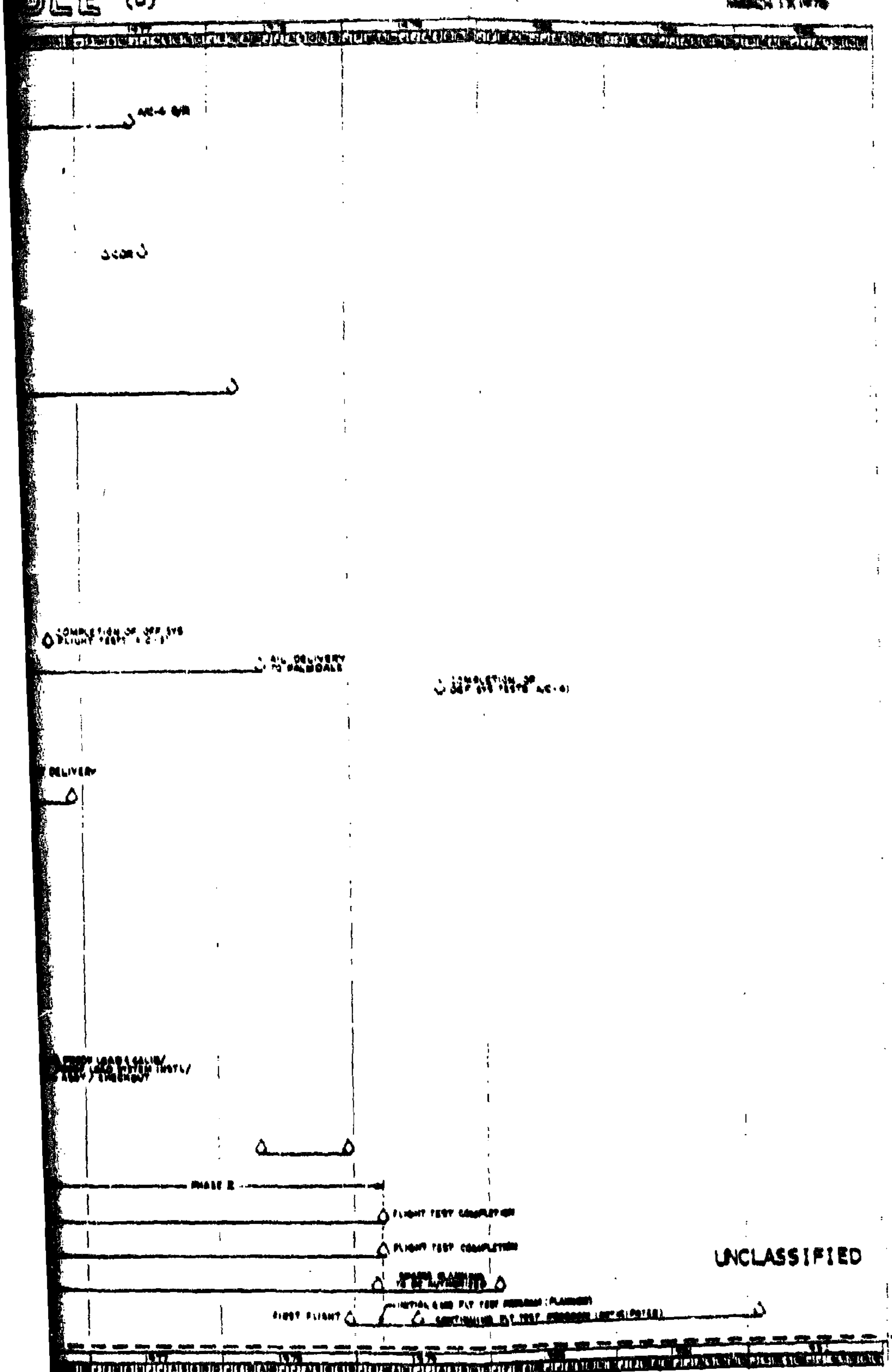
Appendix H

B-1 MASTER PROGRAM SCHEDULE

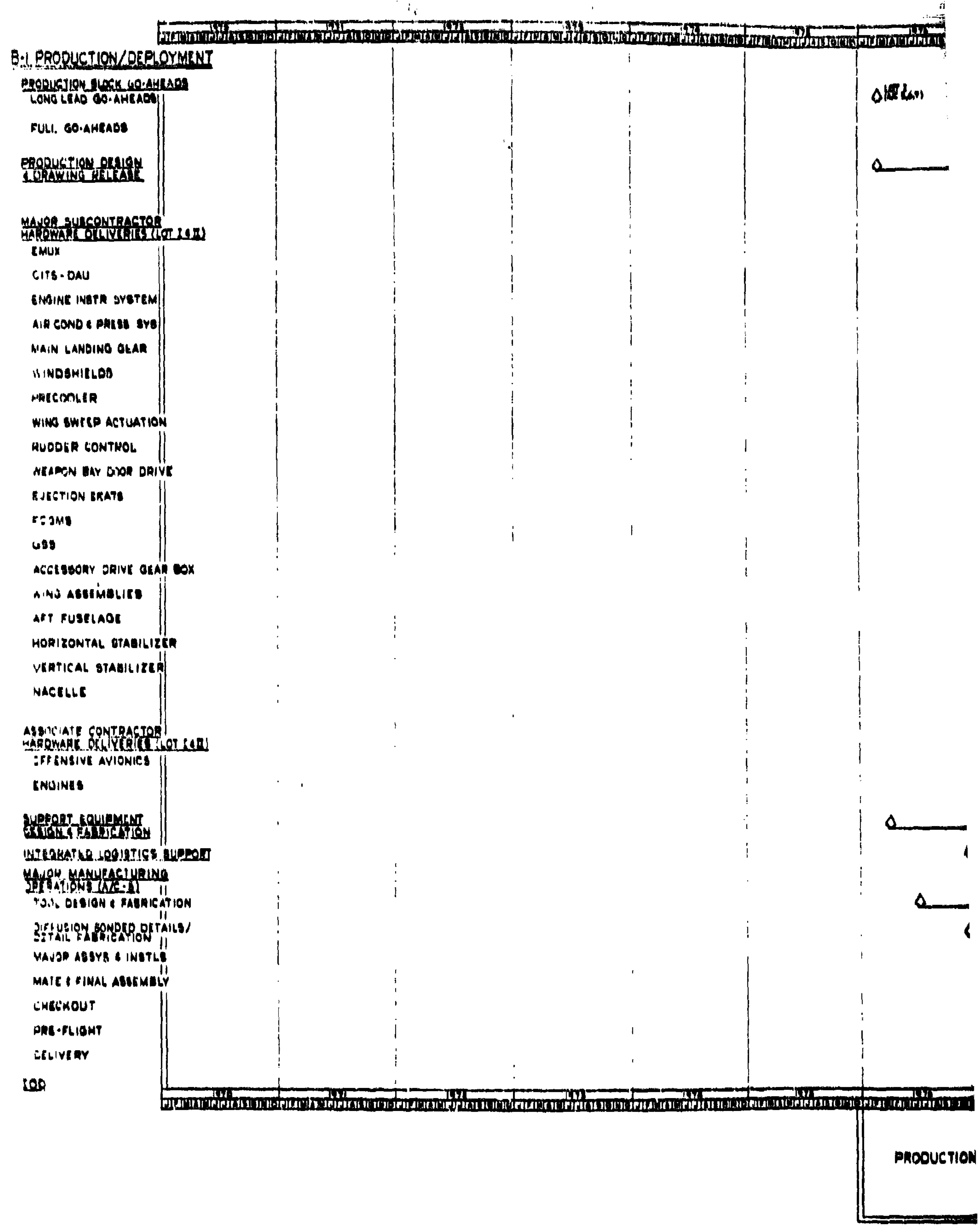
(U) B-1 MASTER PROGRAM SCHED



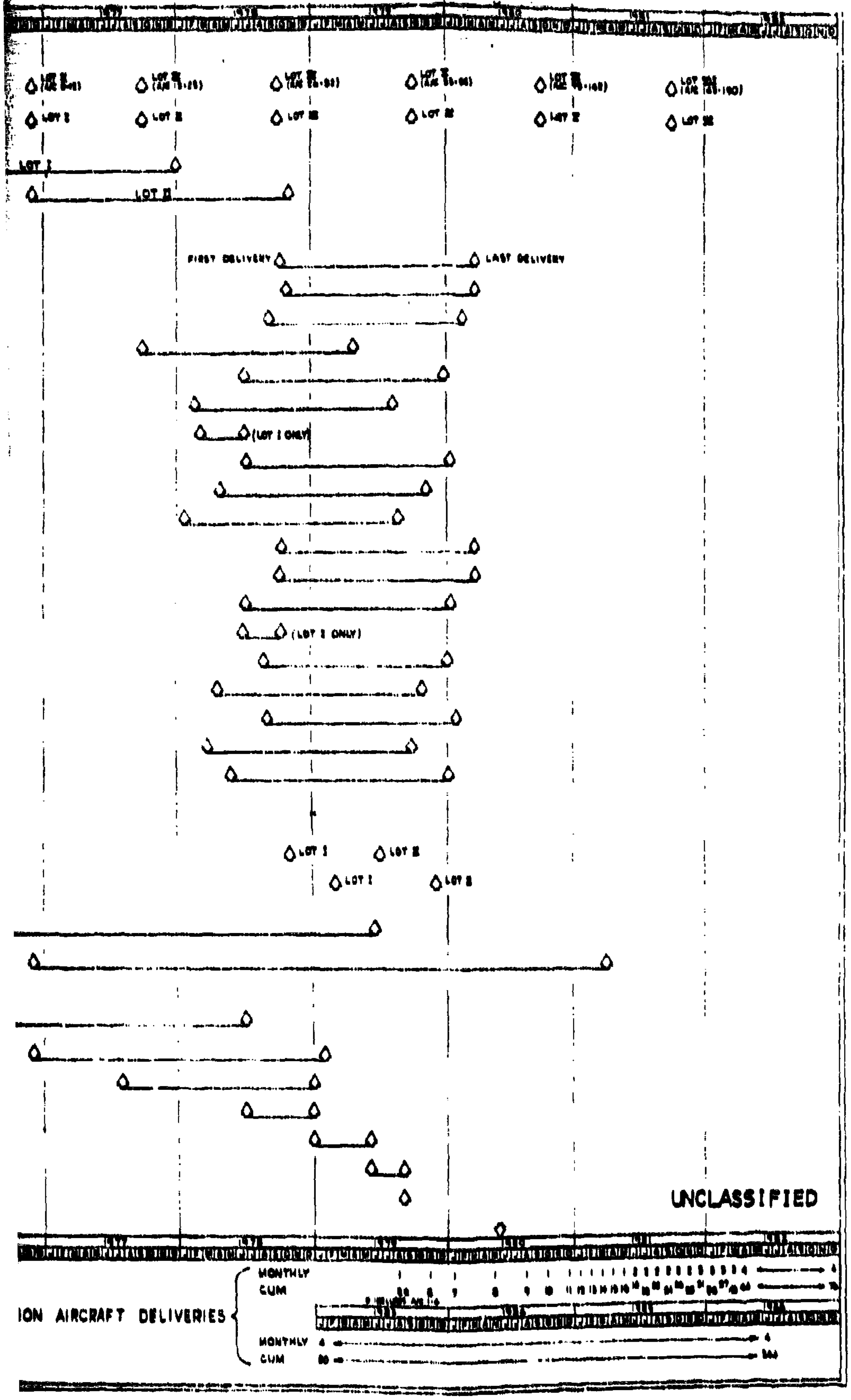
ULE (U)

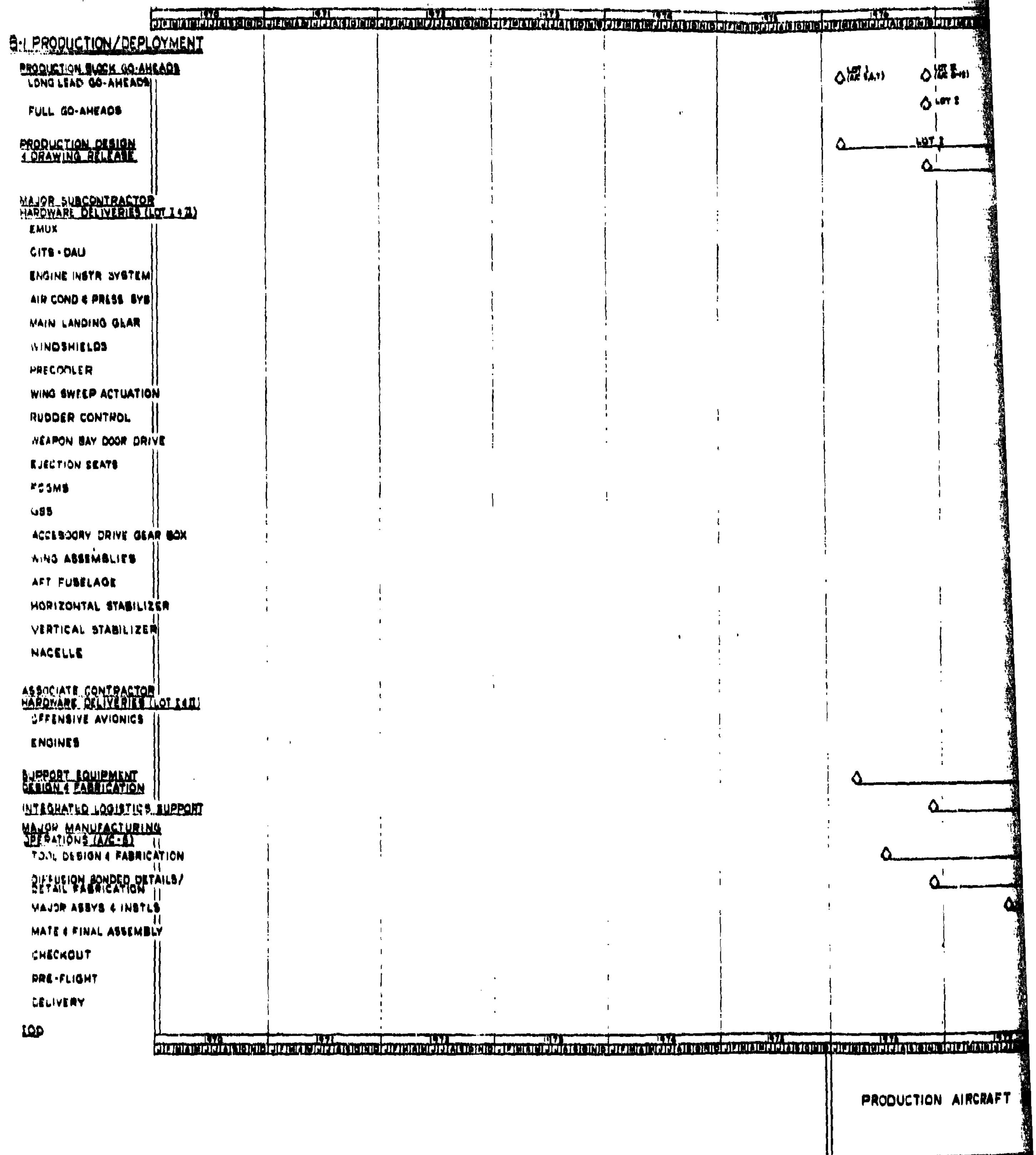


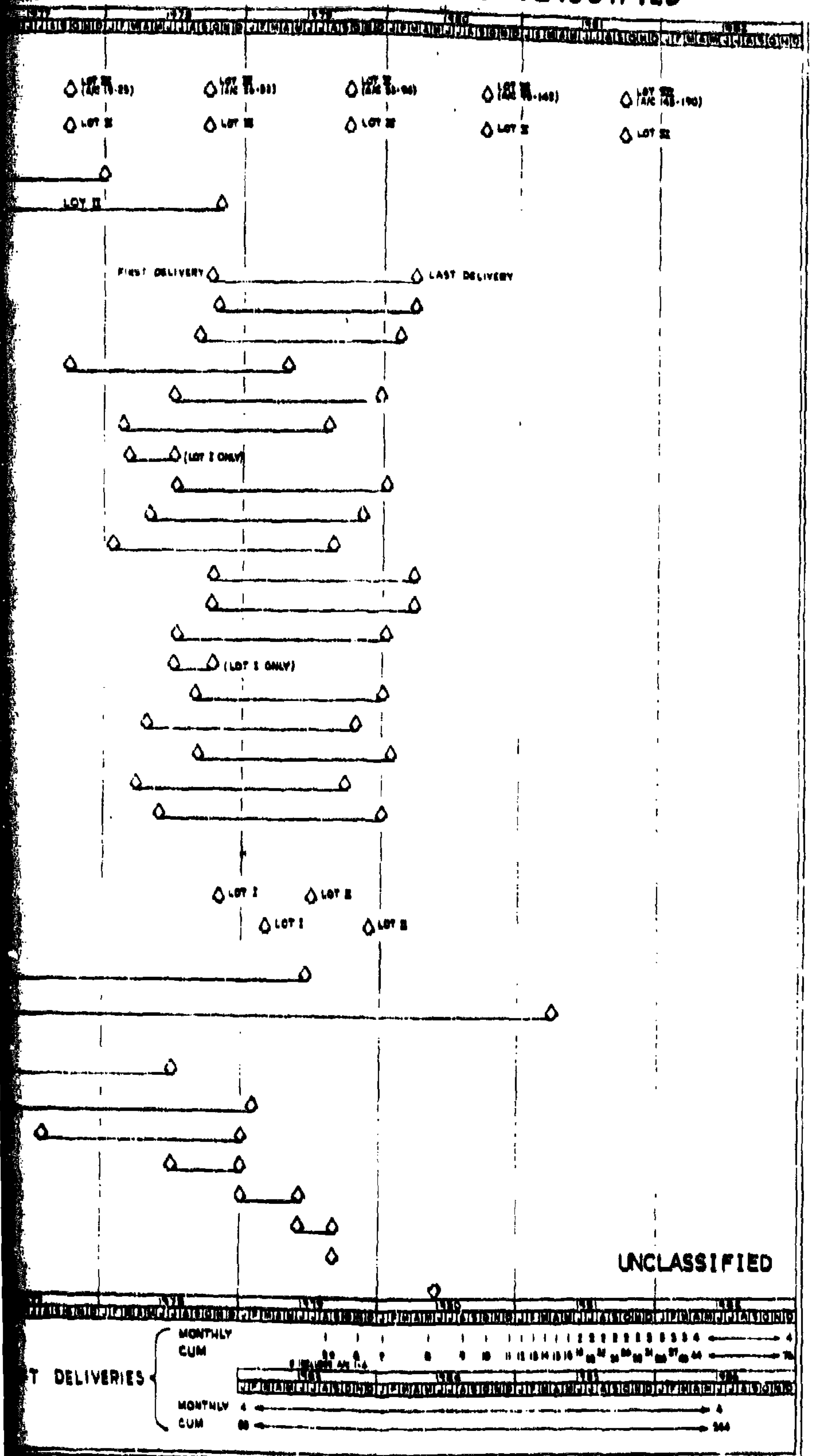
UNCLASSIFIED



B-1 PRODUCTION/DEPLOYMENT
PRODUCTION BLOCK GO-AHEADS
LONG LEAD GO-AHEADS
FULL GO-AHEADS
PRODUCTION DESIGN & DRAWING RELEASE
MAJOR SUBCONTRACTOR HARDWARE DELIVERIES (LOT I & II)
EMUX
CITS-DAU
ENGINE INSTR SYSTEM
AIR COND & PRESS SYS
MAIN LANDING GEAR
WINDSHIELDS
PRECOOLER
WING SWEEP ACTUATION
RUDDER CONTROL
WEAPON BAY DOOR DRIVE
EJECTION SEATS
ECOMS
USS
ACCESSORY DRIVE GEAR BOX
WING ASSEMBLIES
AFT FUSELAGE
HORIZONTAL STABILIZER
VERTICAL STABILIZER
NACELLE
ASSOCIATE CONTRACTOR HARDWARE DELIVERIES (LOT I & II)
OFFENSIVE AVIONICS
ENGINES
SUPPORT EQUIPMENT DESIGN & FABRICATION
INTEGRATED LOGISTICS SUPPORT
MAJOR MANUFACTURING OPERATIONS (A/C-5)
TOOL DESIGN & FABRICATION
DIFFUSION BONDED DETAILS/ DETAIL FABRICATION
MAJOR ASSYS & INSTLS
MATE & FINAL ASSEMBLY
CHECKOUT
PRE-FLIGHT
DELIVERY
IOC
PRODUCTION


FIRST DELIVERY
LAST DELIVERY
(LOT I ONLY)
(LOT I ONLY)
UNCLASSIFIED
MONTHLY
CUM
ION AIRCRAFT DELIVERIES
MONTHLY
CUM

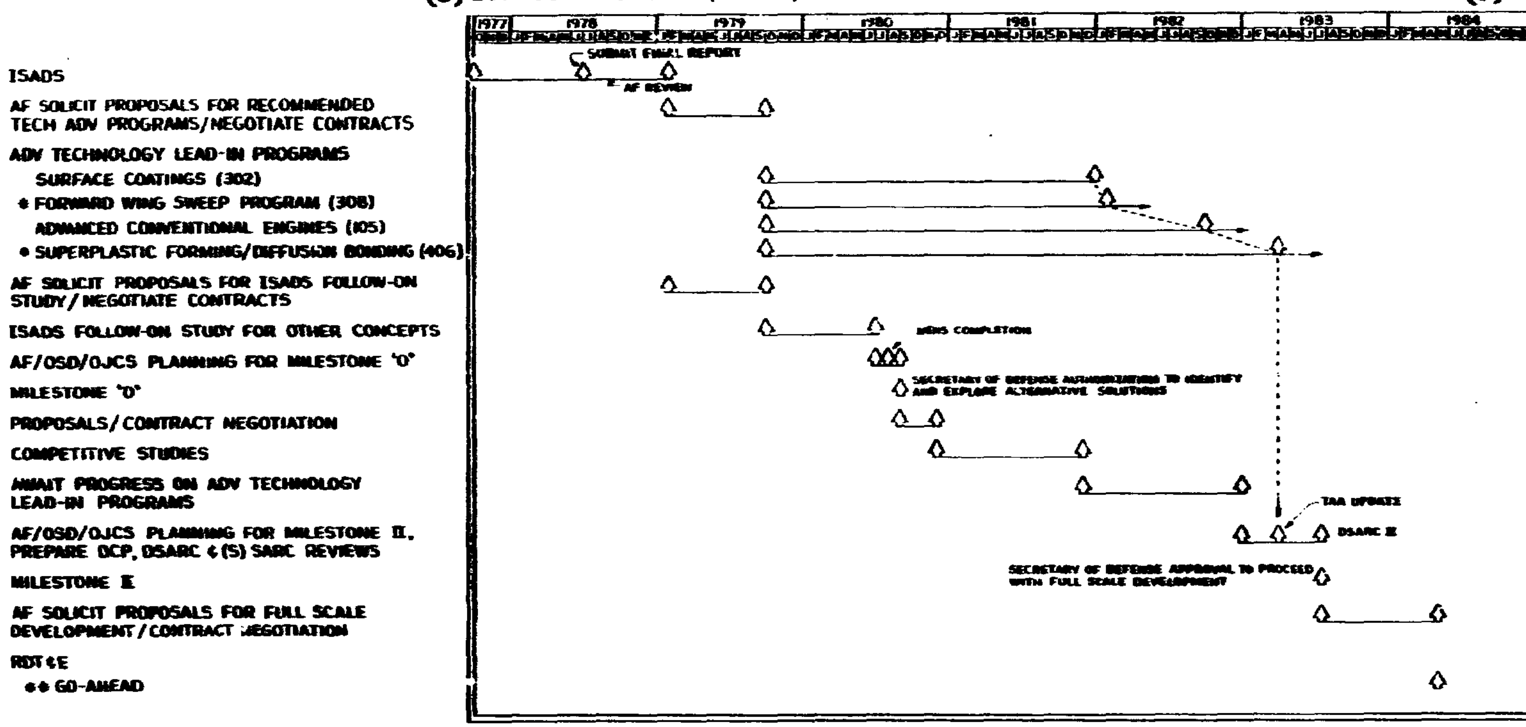

B-1 PRODUCTION/DEPLOYMENT
PRODUCTION BLOCK GO-AHEADS
LONG LEAD GO-AHEADS
FULL GO-AHEADS
PRODUCTION DESIGN & DRAWING RELEASE
LOT 1
MAJOR SUBCONTRACTOR HARDWARE DELIVERIES (LOT I & II)
EMUX
CITS - DAU
ENGINE INSTR SYSTEM
AIR COND & PRESS SYS
MAIN LANDING GEAR
WINDSHIELDS
PRECOOLER
WING SWEEP ACTUATION
RUDDER CONTROL
WEAPON BAY DOOR DRIVE
EJECTION SEATS
GSS
ACCESSORY DRIVE GEAR BOX
WING ASSEMBLIES
AFT FUSELAGE
HORIZONTAL STABILIZER
VERTICAL STABILIZER
NACELLE
ASSOCIATE CONTRACTOR HARDWARE DELIVERIES (LOT I & II)
OFFENSIVE AVIONICS
ENGINES
SUPPORT EQUIPMENT DESIGN & FABRICATION
INTEGRATED LOGISTICS SUPPORT
MAJOR MANUFACTURING OPERATIONS (A/C-8)
TOOL DESIGN & FABRICATION
DIFFUSION BONDED DETAILS/ DETAIL FABRICATION
MAJOR ASSYS & INSTLS
MATE & FINAL ASSEMBLY
CHECKOUT
PRE-FLIGHT
DELIVERY
IOD
PRODUCTION AIRCRAFT


LOT II
FIRST DELIVERY
LAST DELIVERY
(LOT I ONLY)
(LOT I ONLY)
UNCLASSIFIED
MONTHLY
CUM
T DELIVERIES
MONTHLY
CUM

Appendix I

BASELINE PRE-RDT&E PROGRAM SCHEDULES

(U) LOW COST CONCEPT (D645-1) MASTER PROGRAM SCHEDULE (TIME NOW TO RDT&E GO-AHEAD) (U)

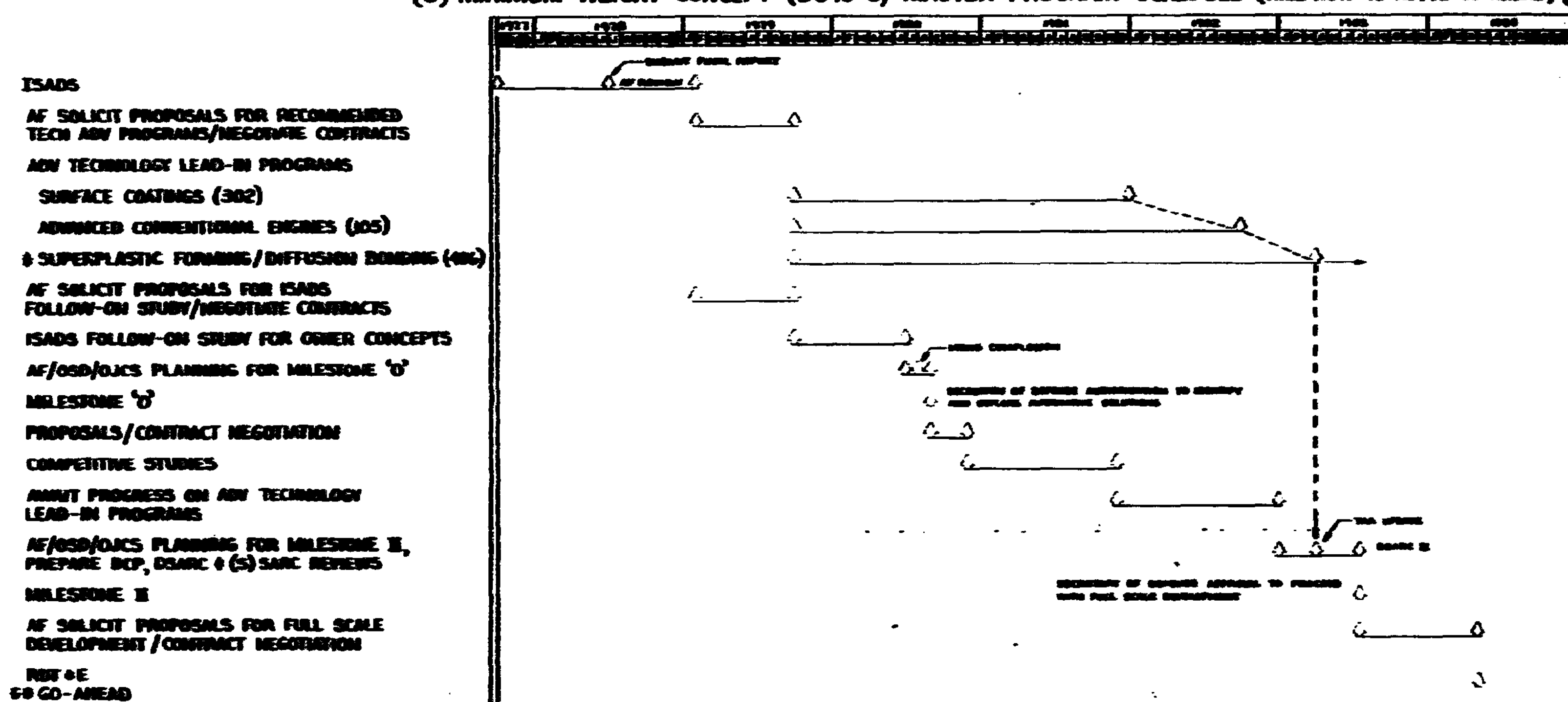


UNCLASSIFIED

* FOLLOW-ON TO ON-GOING ADVANCED TECHNOLOGY PROGRAMS

** SEE APPENDIX J FOR SCHEDULE DETAILS AFTER RDT&E GO-AHEAD

(U) MINIMUM WEIGHT CONCEPT (D645-6) MASTER PROGRAM SCHEDULE (TIME NOW TO RDT&E GO-AHEAD) (U)

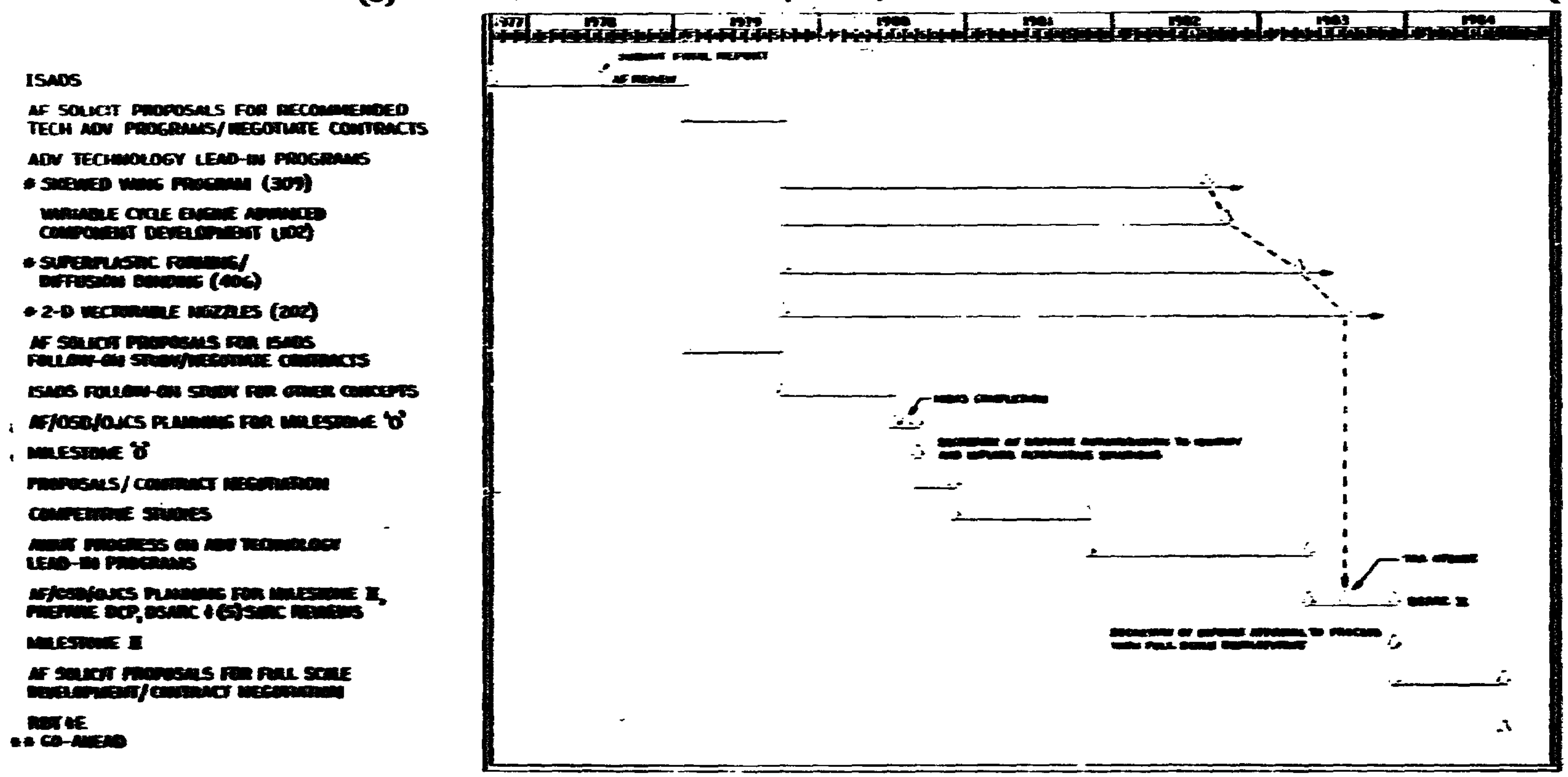


* FOLLOW-ON TO ON-GOING ADVANCED TECHNOLOGY PROGRAMS

** SEE FIGURE APPENDIX J FOR SCHEDULE DETAILS AFTER RDT&E GO-AHEAD

UNCLASSIFIED

(U) MINIMUM PENETRATION CONCEPT (D645-3) MASTER PROGRAM SCHEDULE (TIME NOW TO RDT&E GO-AHEAD) (U)

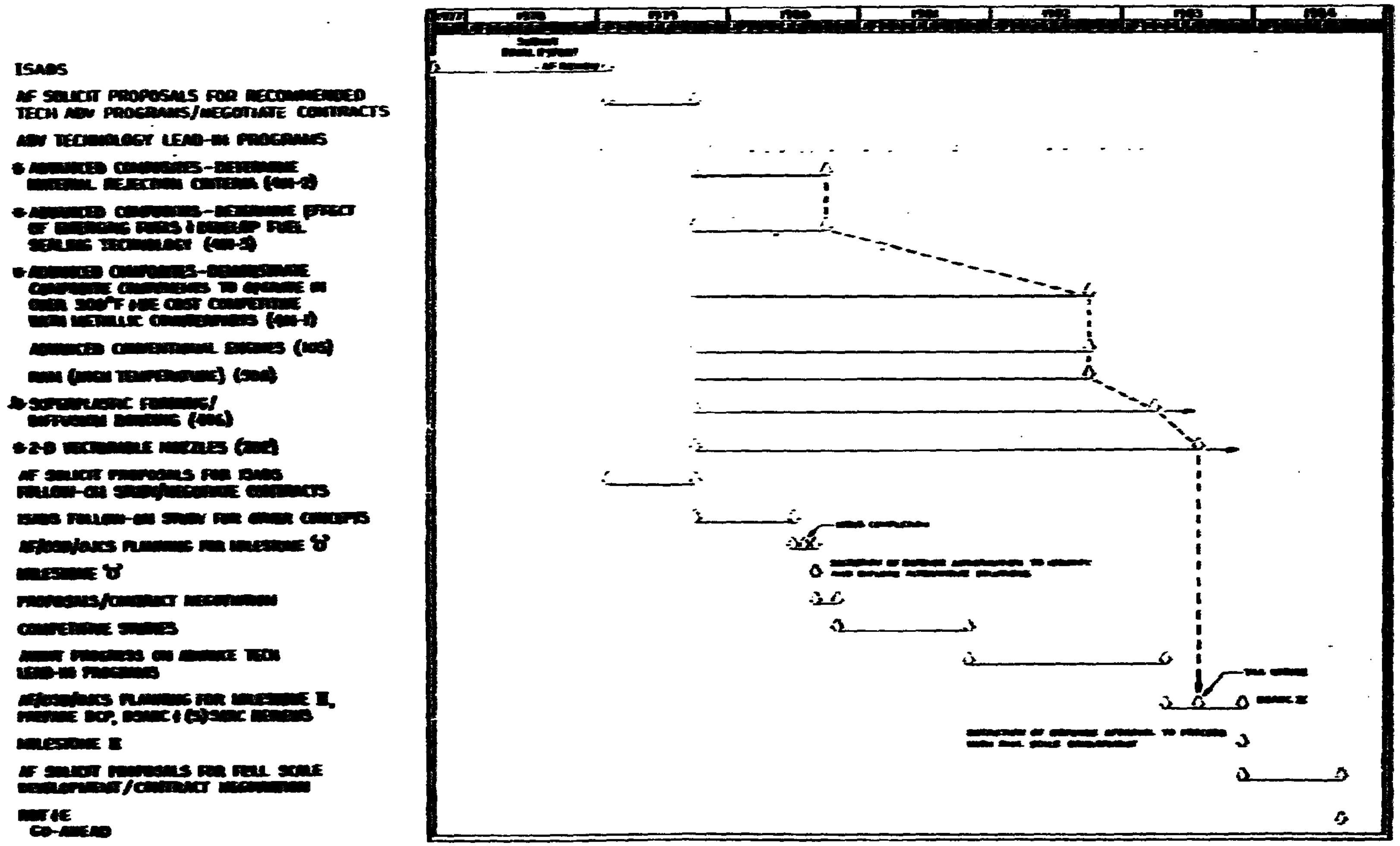


* FOLLOW-ON TO ONGOING ADVANCED TECHNOLOGY PROGRAMS

** SEE FIGURE APPENDIX J FOR SCHEDULE DETAILS AFTER RDT&E GO-AHEAD

UNCLASSIFIED

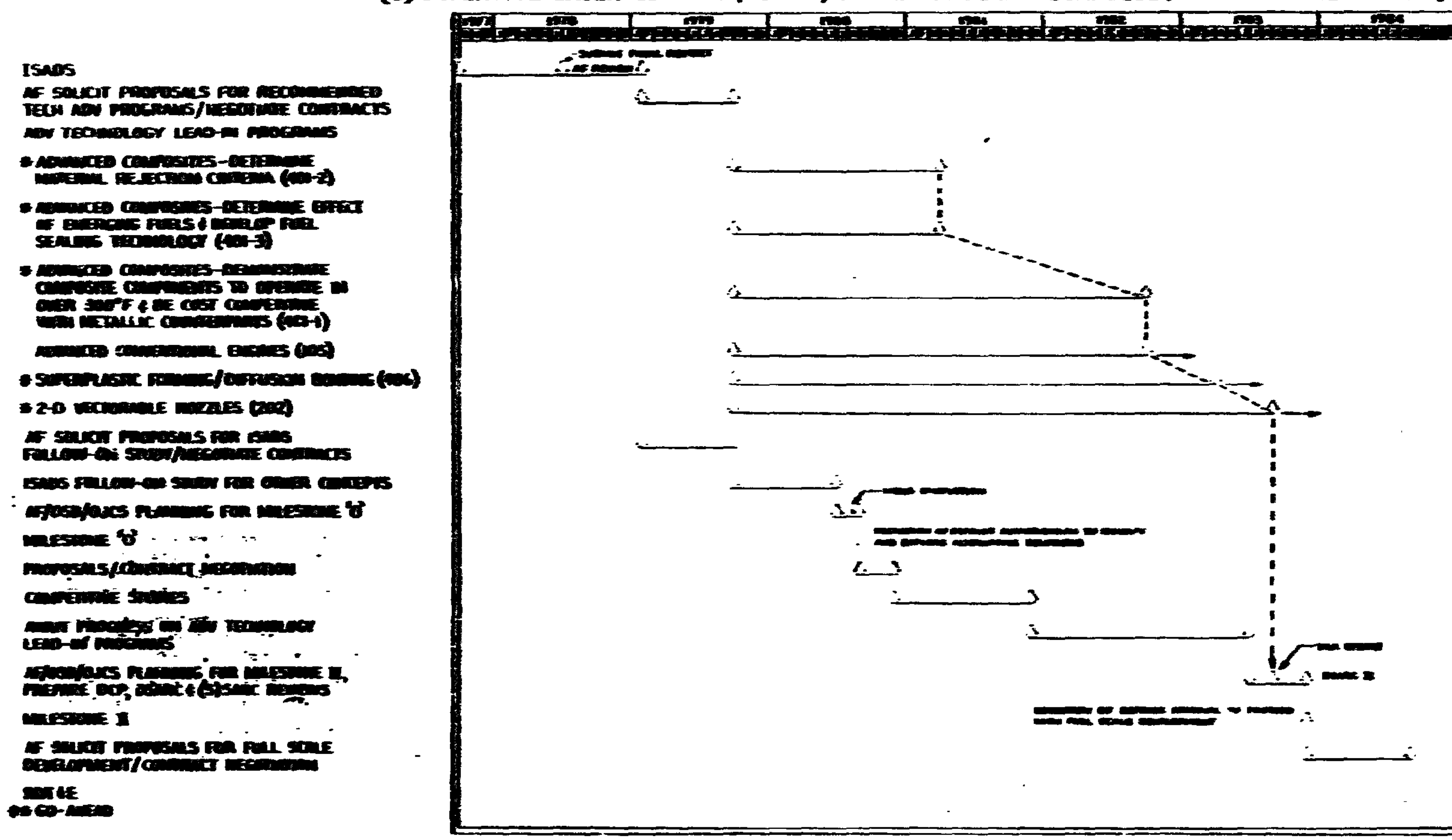
(U) STEALTH CONCEPT (D645-4) MASTER PROGRAM SCHEDULE (U)



* FOLLOW-ON TO ON-GOING ADVANCED TECHNOLOGY PROGRAMS

UNCLASSIFIED

(U) DEFENSIVE LASER CONCEPT (D645-5) MASTER PROGRAM SCHEDULE (TIME NOW TO RDT&E GO-AHEAD) (U)



* FOLLOW-ON TO ON-GOING ADVANCED TECHNOLOGY PROGRAMS

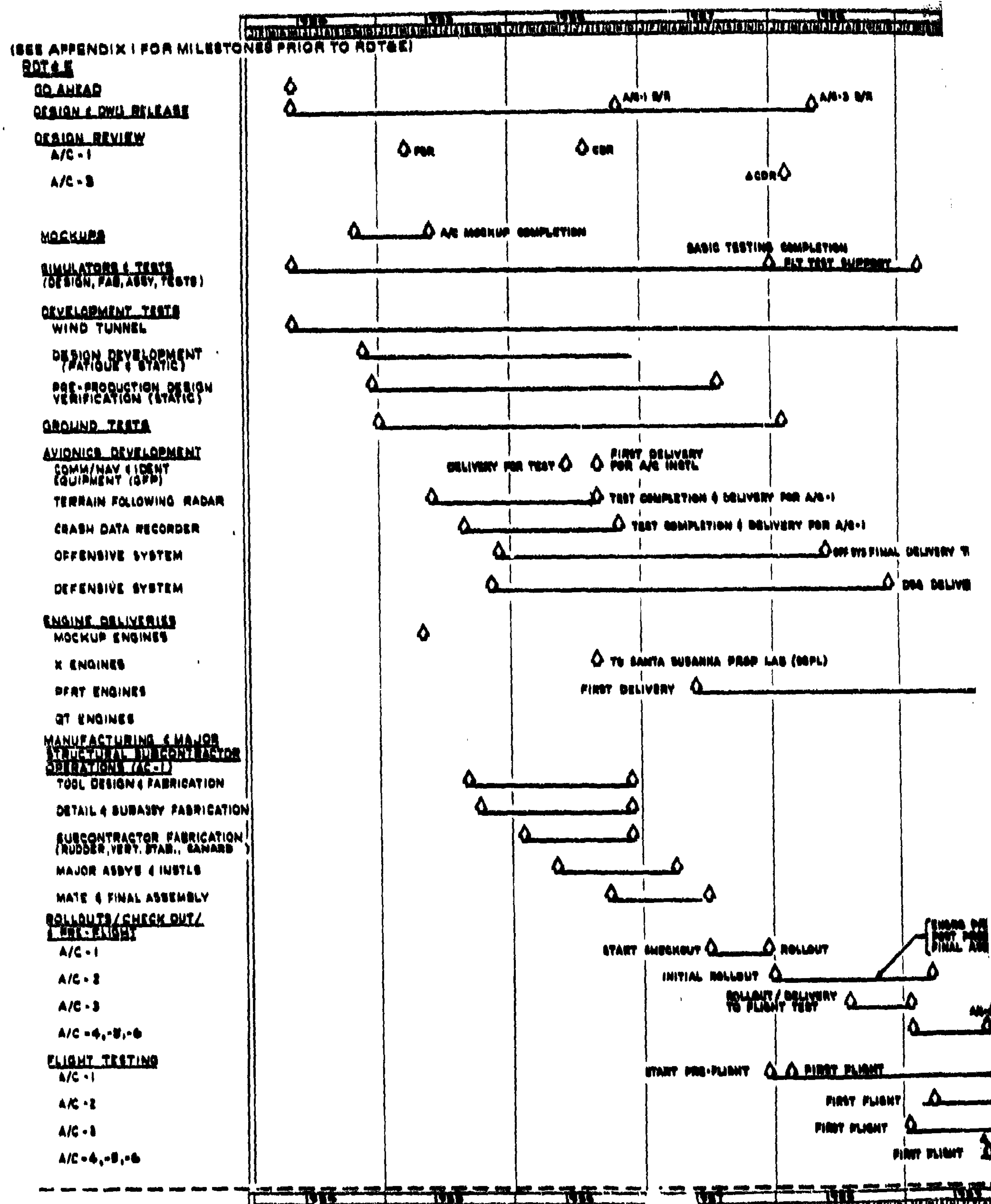
** SEE FIGURE APPENDIX J FOR SCHEDULE DETAILS AFTER RDT&E GO-AHEAD

UNCLASSIFIED

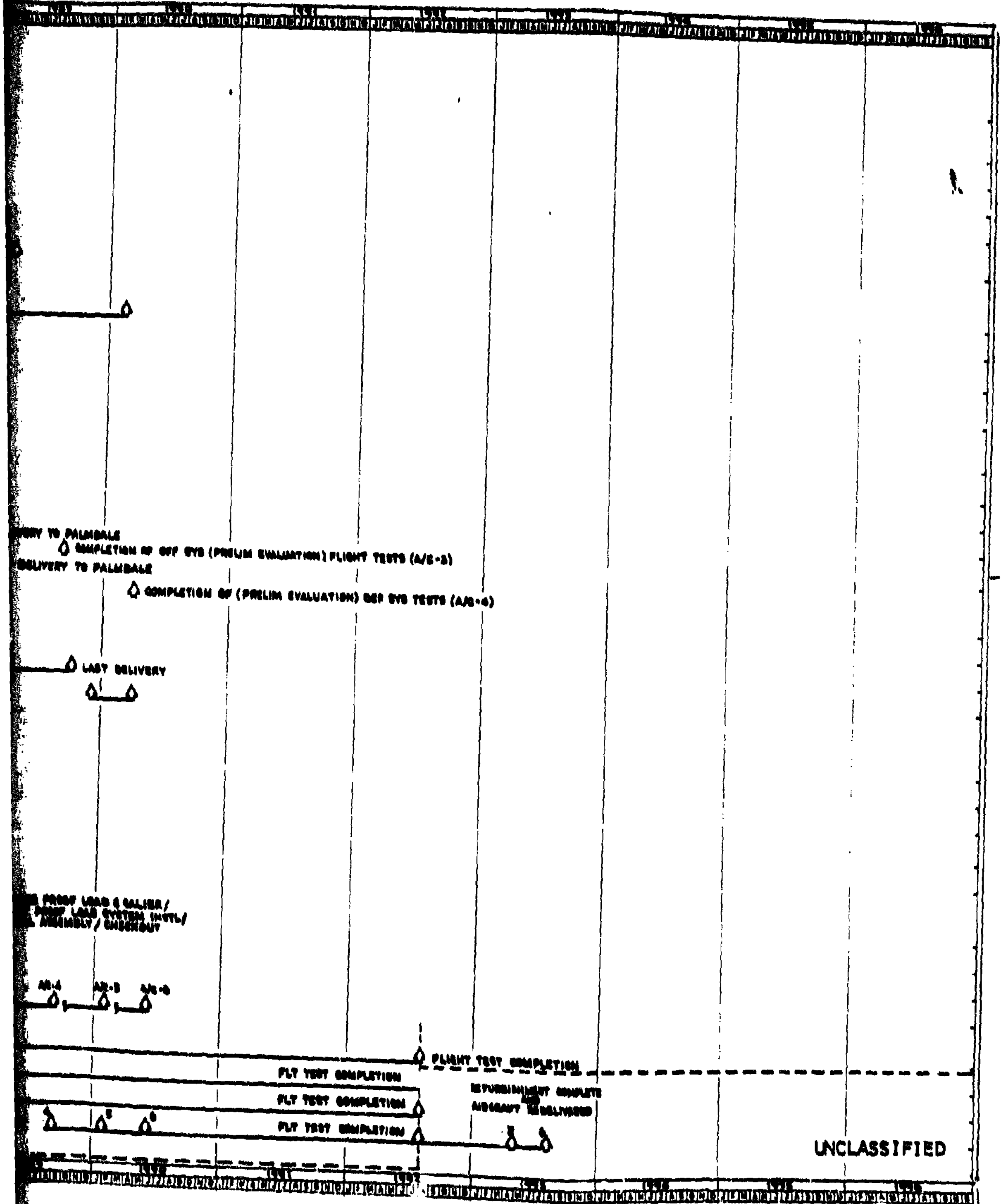
Appendix J

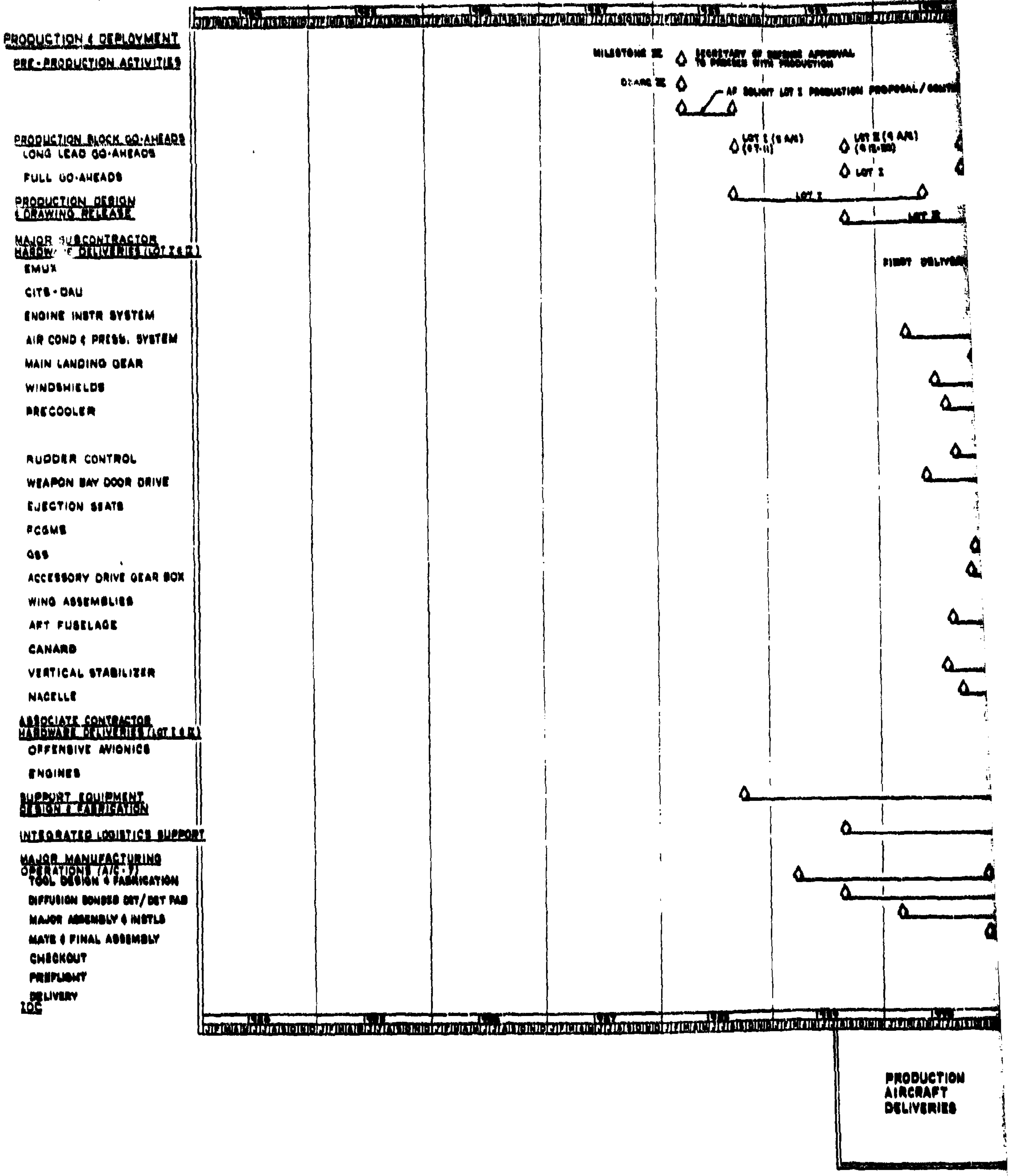
BASELINE RDT&E AND PRODUCTION PROGRAM SCHEDULES

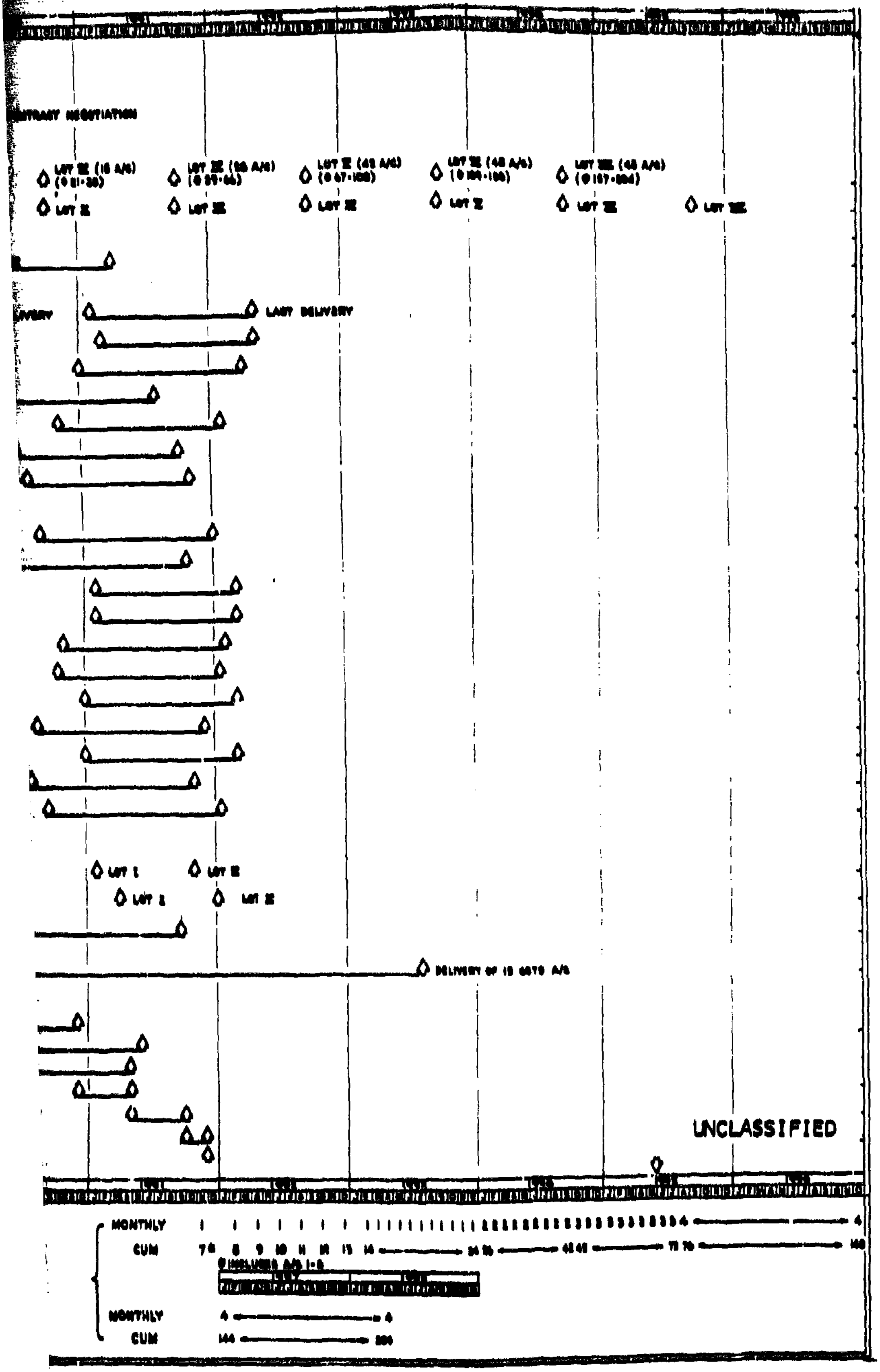
(U) LOW COST CONCEPT (D645-1) MASTER P



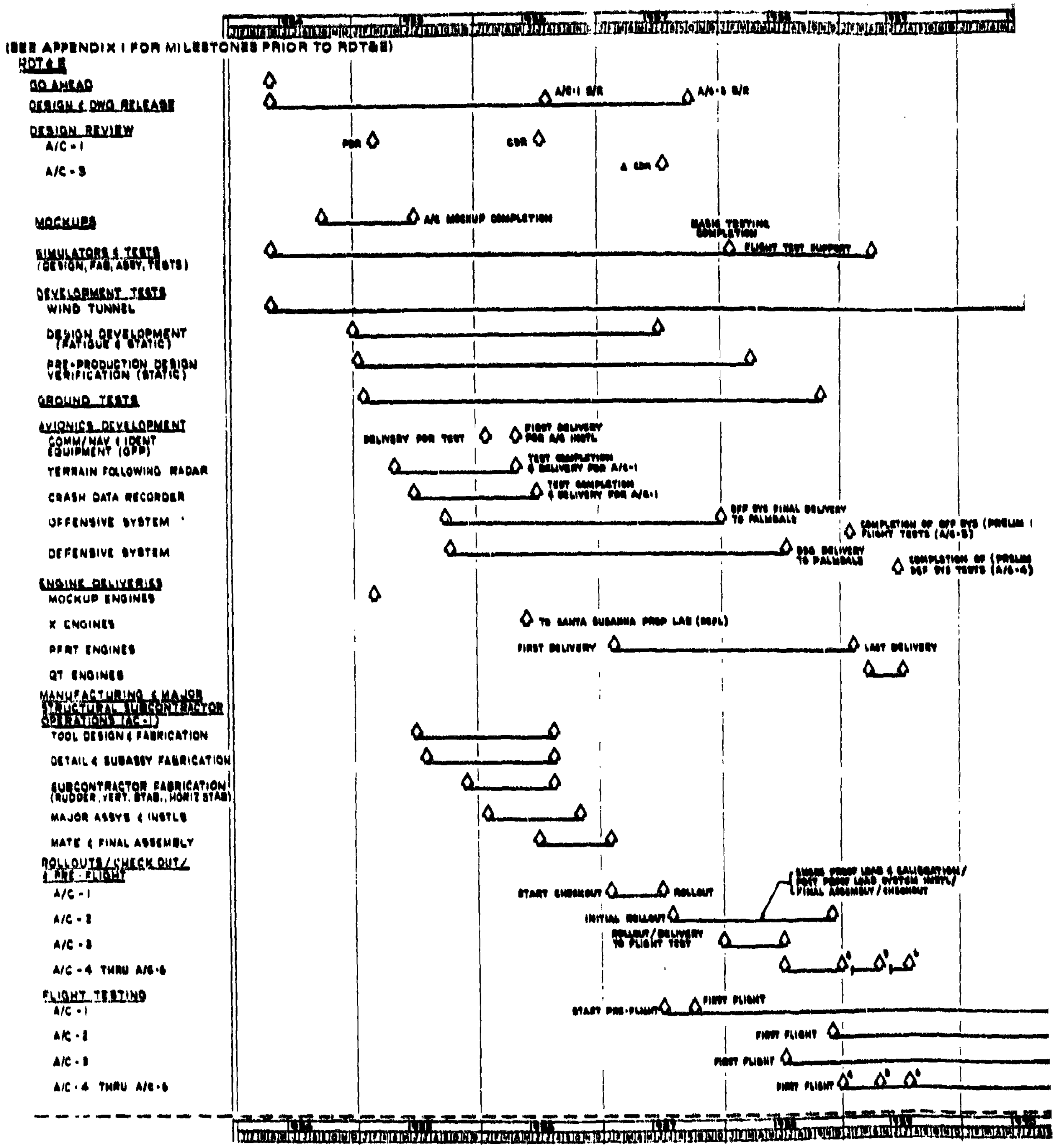
PROGRAM SCHEDULE (RDT&E THRU PRODUCTION/DEPLOYMENT) (U)



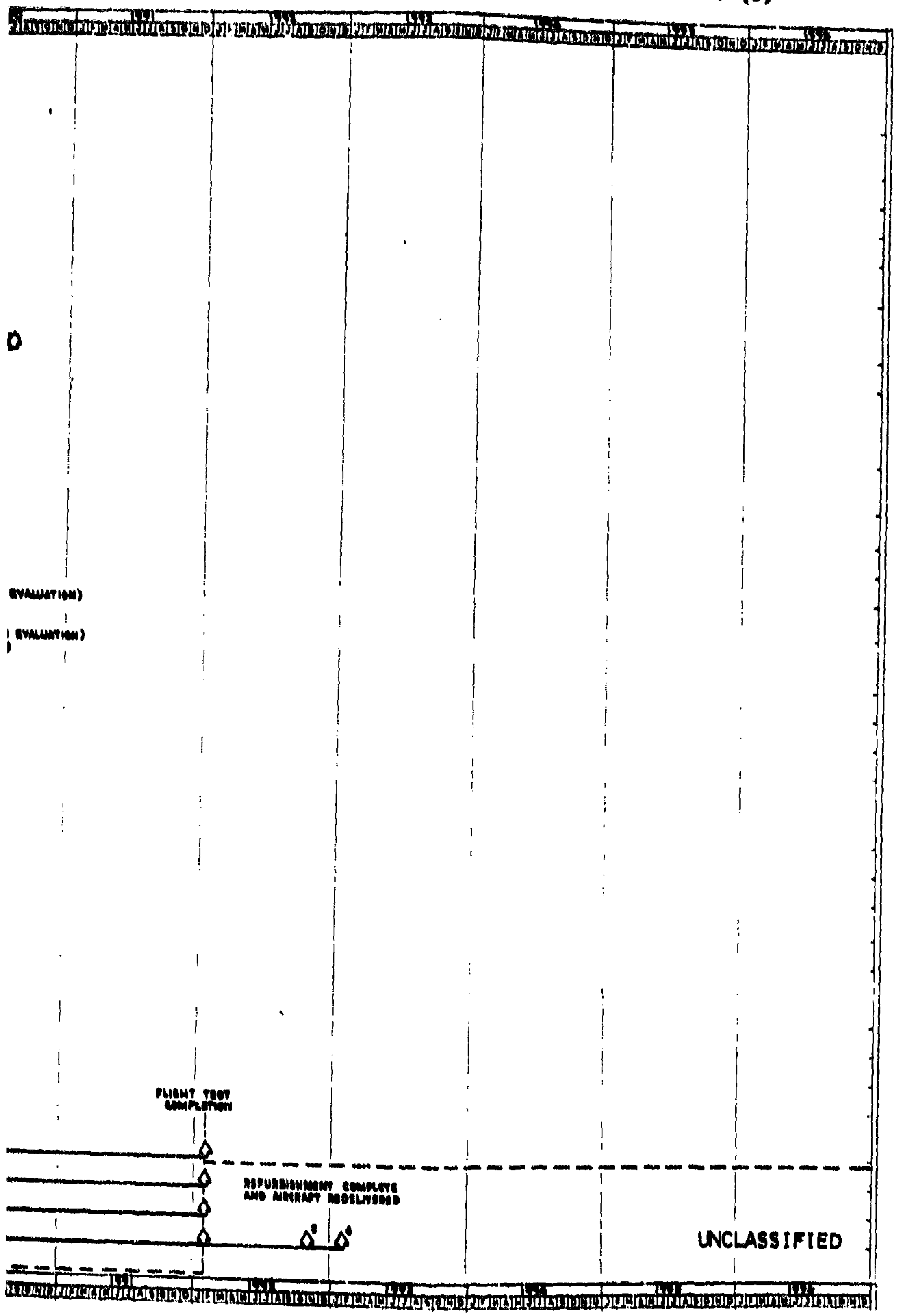

PRODUCTION & DEPLOYMENT
PRE-PRODUCTION ACTIVITIES
MILESTONE III
SECRETARY OF DEFENSE APPROVAL TO PROCEED WITH PRODUCTION
DSARC III
AF SOLICIT LOT I PRODUCTION PROPOSAL/
PRODUCTION BLOCK GO-AHEADS
LONG LEAD GO-AHEADS
LOT I (5 A/C) (87-11)
LOT II (4 A/C)
FULL GO-AHEADS
LOT I
PRODUCTION DESIGN & DRAWING RELEASE
LOT I
LOT II
MAJOR SUBCONTRACTOR HARDWARE DELIVERIES (LOT I & II)
FIRST DELIVERY
EMUX
CITS-DAU
ENGINE INSTR SYSTEM
AIR COND & PRESS. SYSTEM
MAIN LANDING GEAR
WINDSHIELDS
PRECOOLER
RUDDER CONTROL
WEAPON BAY DOOR DRIVE
EJECTION SEATS
FCGMS
GSS
ACCESSORY DRIVE GEAR BOX
WING ASSEMBLIES
AFT FUSELAGE
CANARD
VERTICAL STABILIZER
NACELLE
ASSOCIATE CONTRACTOR HARDWARE DELIVERIES (LOT I & II)
OFFENSIVE AVIONICS
ENGINES
SUPPORT EQUIPMENT DESIGN & FABRICATION
INTEGRATED LOGISTICS SUPPORT
MAJOR MANUFACTURING OPERATIONS (A/C-7)
TOOL DESIGN & FABRICATION
DIFFUSION BONDED DET/DET FAB
MAJOR ASSEMBLY & INSTLS
MATE & FINAL ASSEMBLY
CHECKOUT
PREFLIGHT
DELIVERY
IOC
PRODUCTION AIRCRAFT DELIVERIES


LAST DELIVERY
UNCLASSIFIED
MONTHLY
CUM
MONTHLY
CUM

(U) MINIMUM WEIGHT CONCEPT (D645-6) MASTER PROGR



AM SCHEDULE (RDT&E THRU PRODUCTION/DEPLOYMENT) (U)



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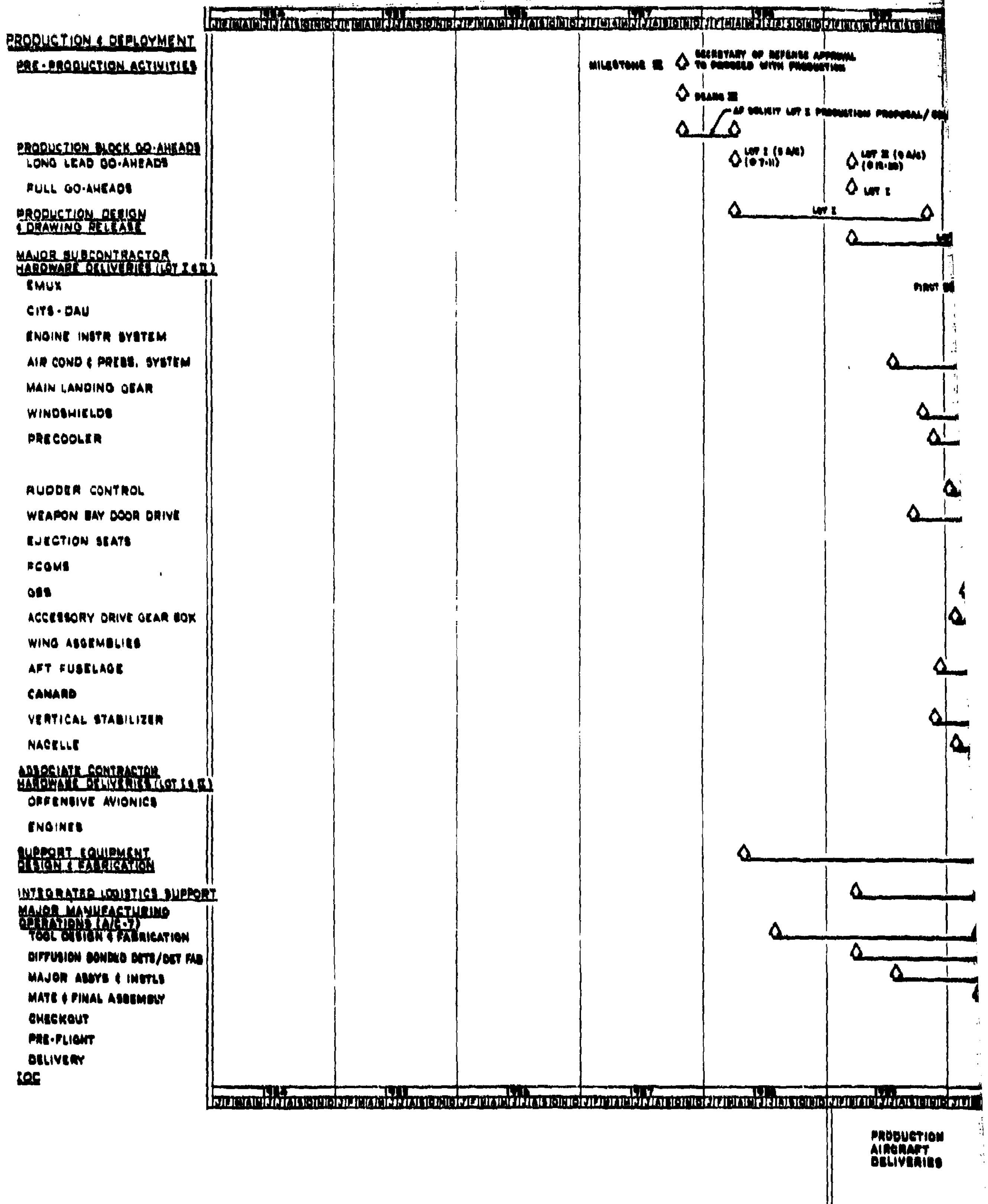
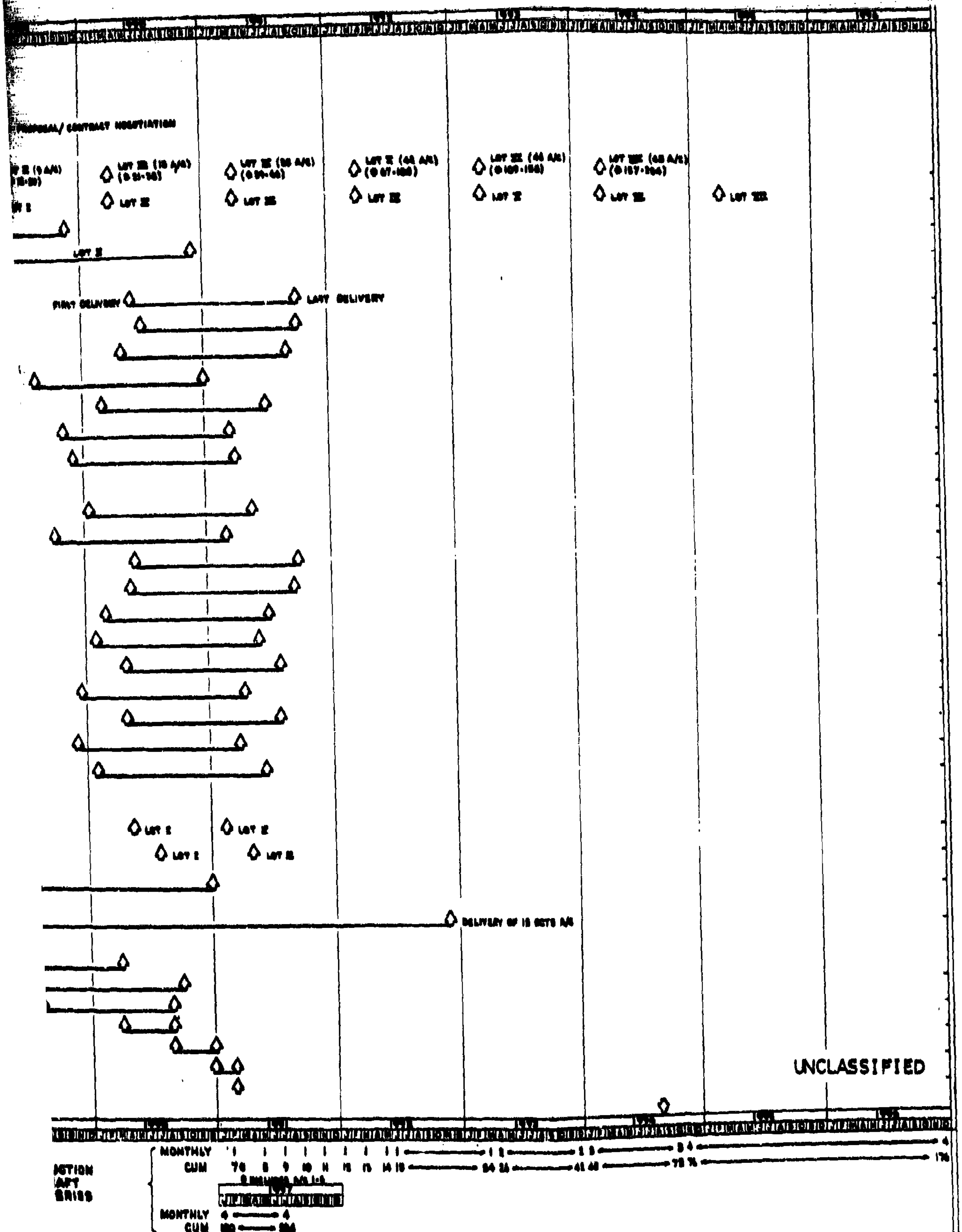
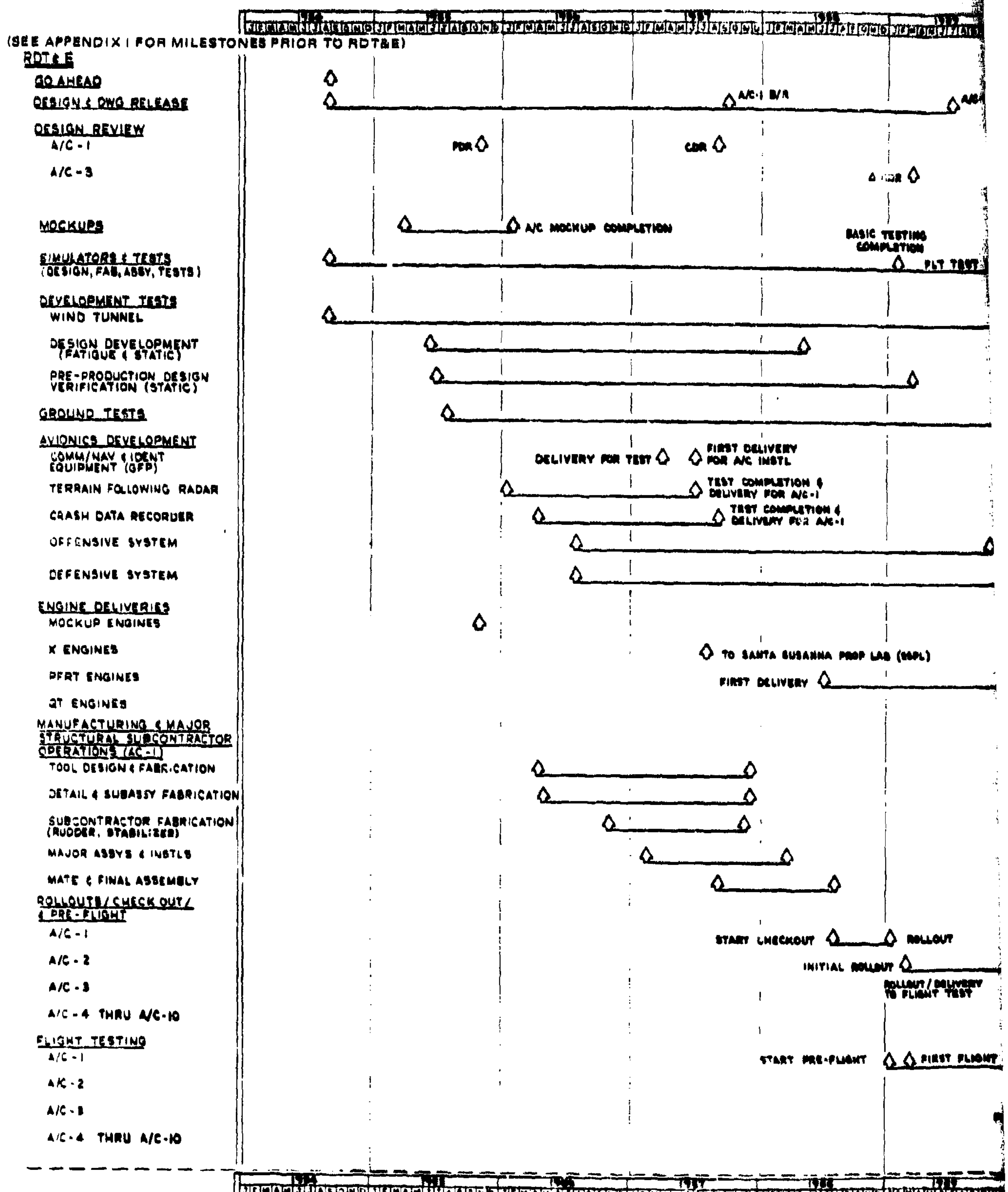


PRODUCTION & DEPLOYMENT
PRE-PRODUCTION ACTIVITIES
MILESTONE III
SECRETARY OF DEFENSE APPROVAL TO PROCEED WITH PRODUCTION
DSARC III
AF SOLICIT LOT I PRODUCTION PROPOSAL/
PRODUCTION BLOCK GO-AHEADS
LONG LEAD GO-AHEADS
FULL GO-AHEADS
LOT I
LOT II
PRODUCTION DESIGN & DRAWING RELEASE
MAJOR SUBCONTRACTOR HARDWARE DELIVERIES (LOT I & II)
EMUX
CITS-DAU
ENGINE INSTR SYSTEM
AIR COND & PRESS. SYSTEM
MAIN LANDING GEAR
WINDSHIELDS
PRECOOLER
RUDDER CONTROL
WEAPON BAY DOOR DRIVE
EJECTION SEATS
FCGMS
GSS
ACCESSORY DRIVE GEAR BOX
WING ASSEMBLIES
AFT FUSELAGE
CANARD
VERTICAL STABILIZER
NACELLE
ASSOCIATE CONTRACTOR HARDWARE DELIVERIES (LOT I & II)
OFFENSIVE AVIONICS
ENGINES
SUPPORT EQUIPMENT DESIGN & FABRICATION
INTEGRATED LOGISTICS SUPPORT
MAJOR MANUFACTURING OPERATIONS (A/C-7)
TOOL DESIGN & FABRICATION
DIFFUSION BONDED DETS/DET FAB
MAJOR ASSYS & INSTLS
MATE & FINAL ASSEMBLY
CHECKOUT
PRE-FLIGHT
DELIVERY
IOC
PRODUCTION AIRCRAFT DELIVERIES


FIRST DELIVERY
LAST DELIVERY
MONTHLY
CUM
MONTHLY
CUM
UNCLASSIFIED

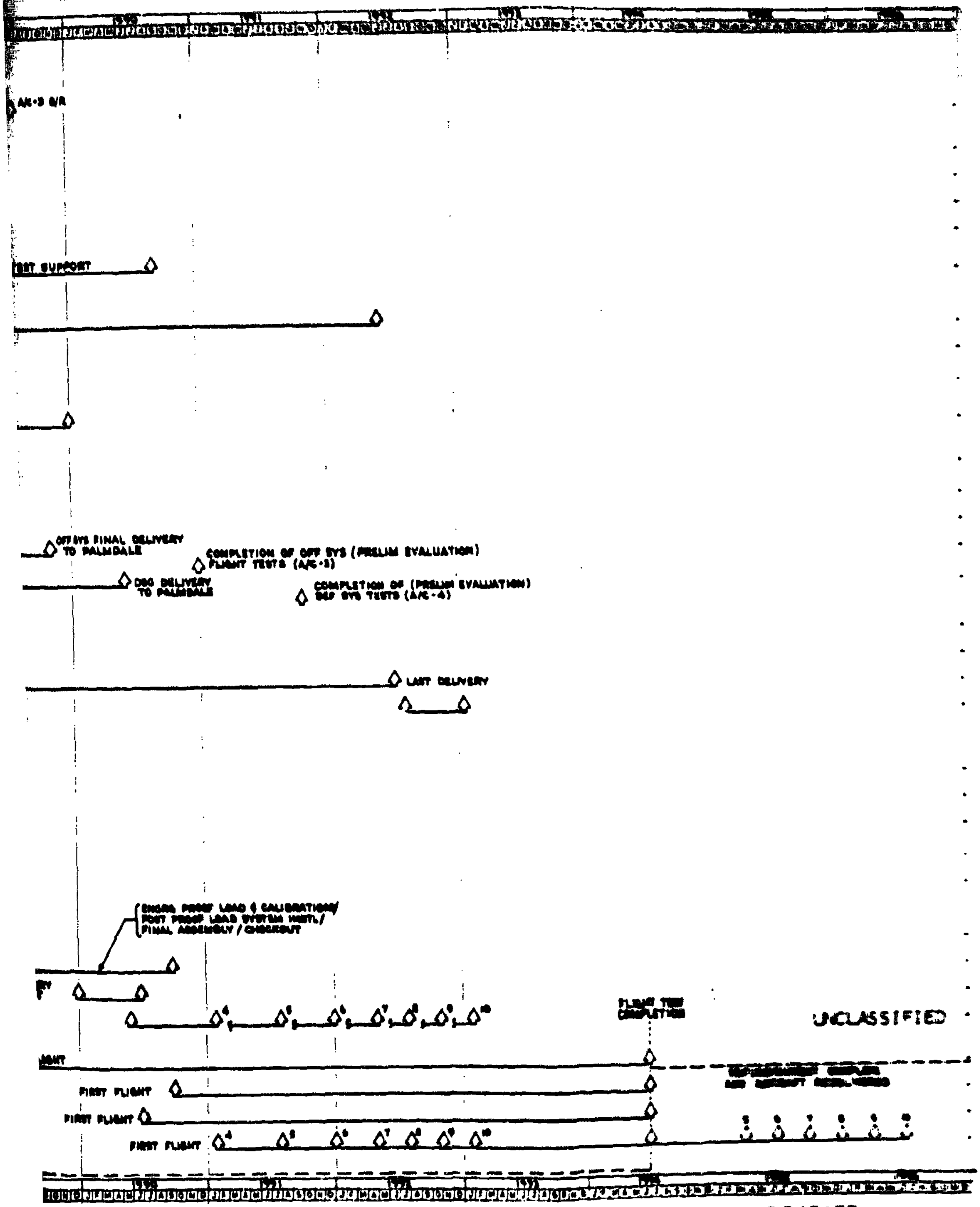
2

(U) MINIMUM PENETRATION TIME CONCEPT (D645-3) M



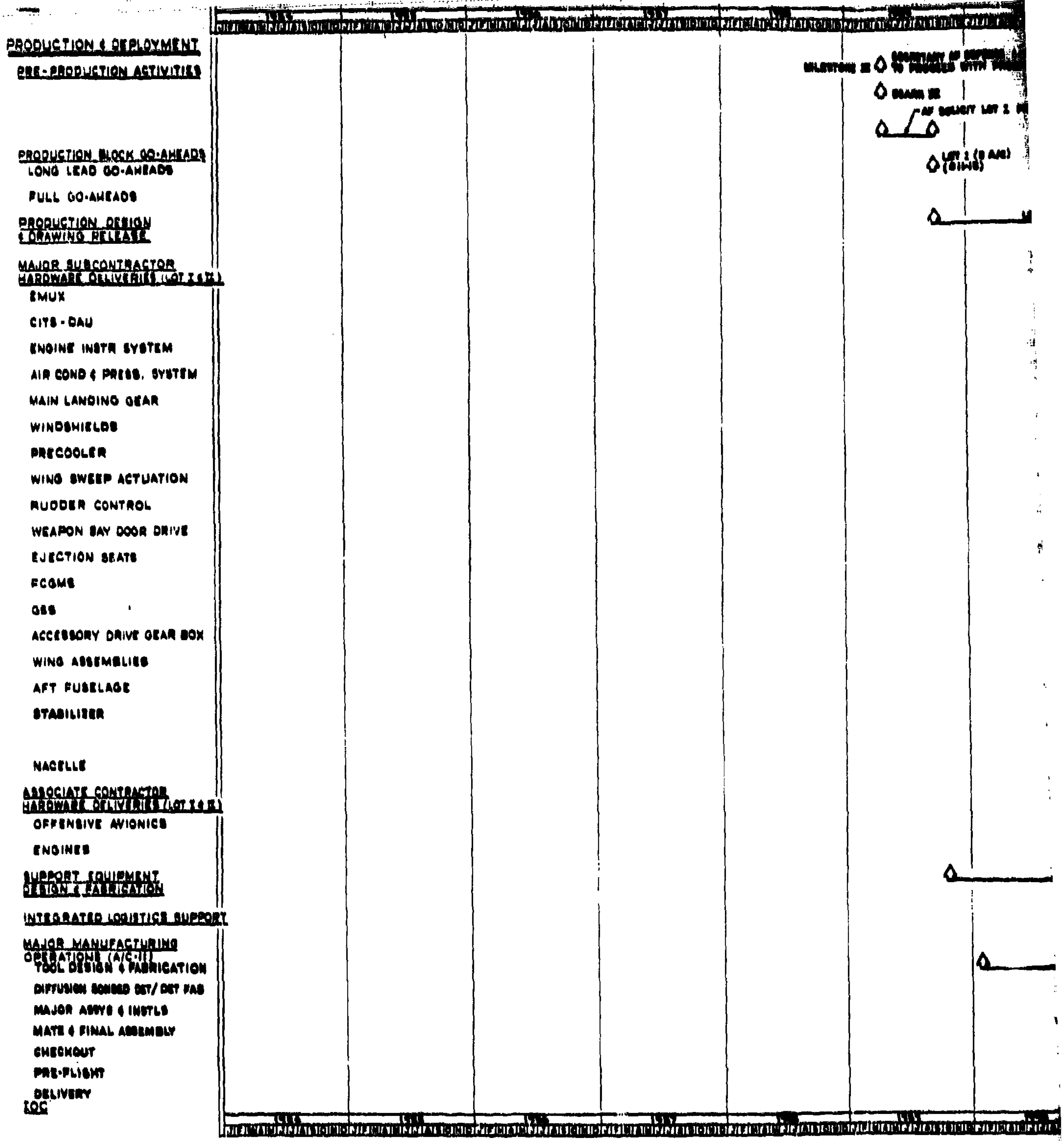
UNCLASSIFIED

MASTER PROGRAM SCHEDULE (RDT&E THRU PRODUCTION/DEPLOYMENT) (U)

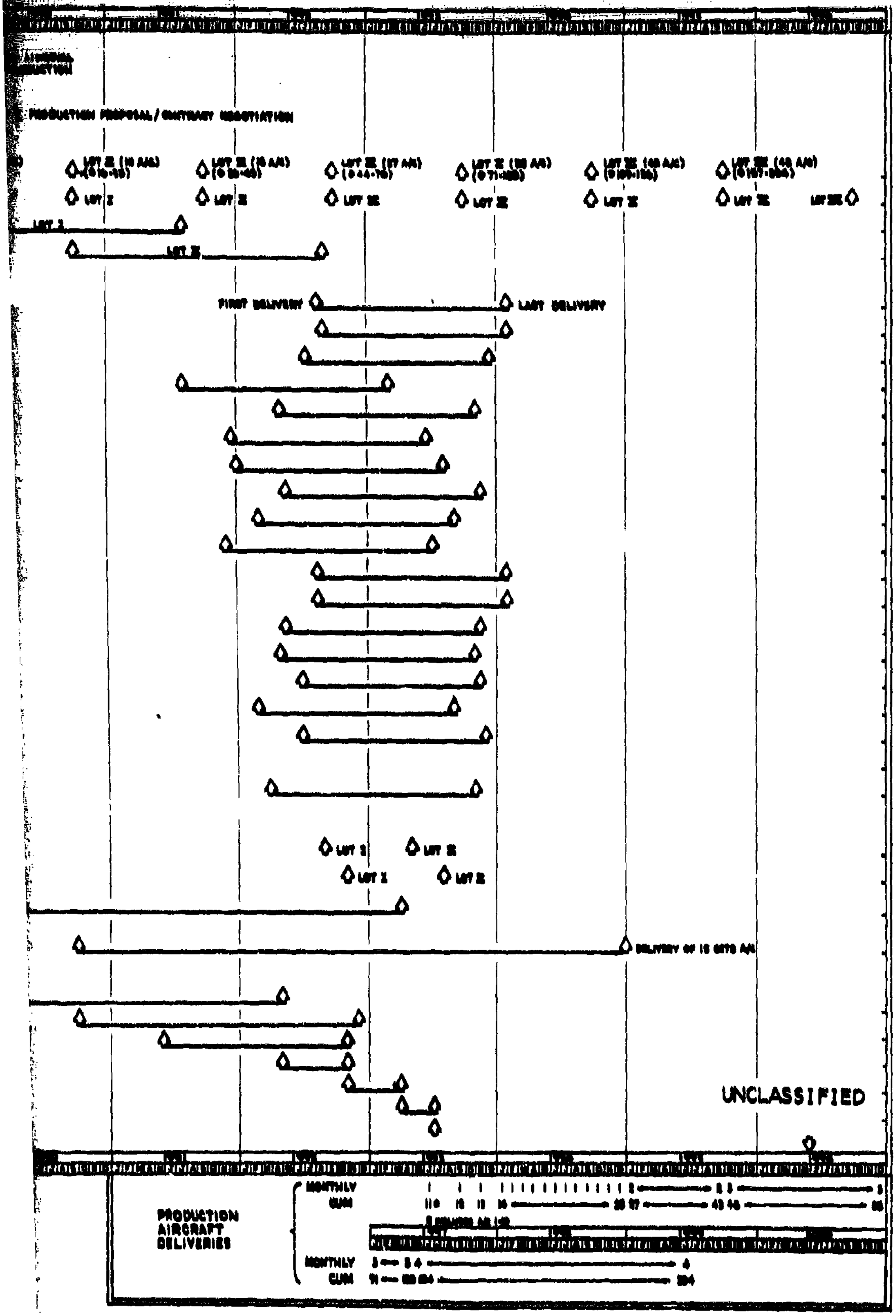


UNCLASSIFIED

.UNCLASSIFIED

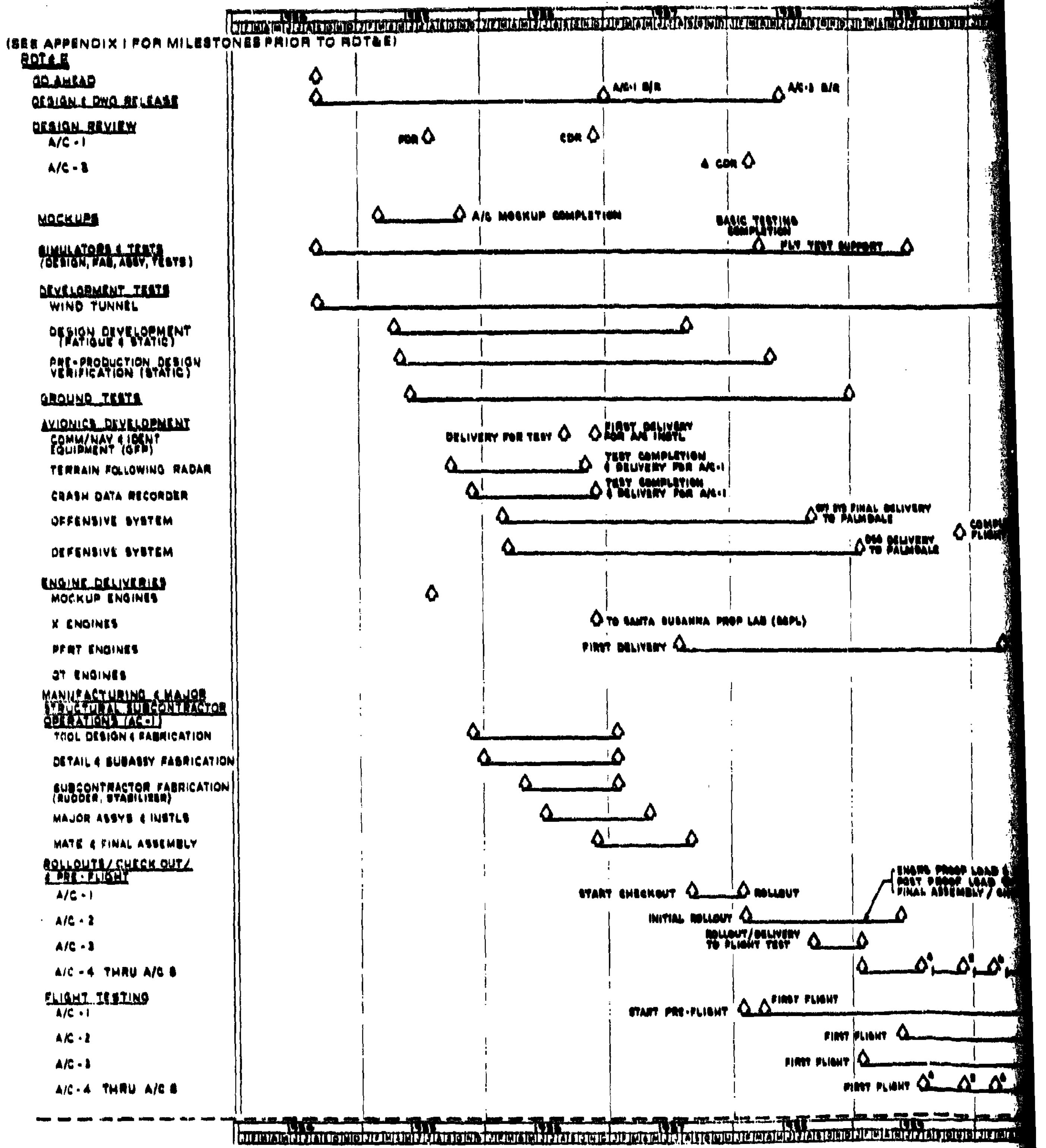


PRODUCTION & DEPLOYMENT
PRE-PRODUCTION ACTIVITIES
PRODUCTION BLOCK GO-AHEADS
LONG LEAD GO-AHEADS
FULL GO-AHEADS
PRODUCTION DESIGN & DRAWING RELEASE
MAJOR SUBCONTRACTOR HARDWARE DELIVERIES (LOT I & II)
EMUX
CITS - DAU
ENGINE INSTR SYSTEM
AIR COND & PRESS. SYSTEM
MAIN LANDING GEAR
WINDSHIELDS
PRECOOLER
WING SWEEP ACTUATION
RUDDER CONTROL
WEAPON BAY DOOR DRIVE
EJECTION SEATS
FCGMS
GSS
ACCESSORY DRIVE GEAR BOX
WING ASSEMBLIES
AFT FUSELAGE
STABILIZER
NACELLE
ASSOCIATE CONTRACTOR HARDWARE DELIVERIES (LOT I & II)
OFFENSIVE AVIONICS
ENGINES
SUPPORT EQUIPMENT DESIGN & FABRICATION
INTEGRATED LOGISTICS SUPPORT
MAJOR MANUFACTURING OPERATIONS (A/C-II)
TOOL DESIGN & FABRICATION
DIFFUSION BONDED DET/DET FAB
MAJOR ASSYS & INSTLS
MATE & FINAL ASSEMBLY
CHECKOUT
PRE-FLIGHT
DELIVERY
IOC

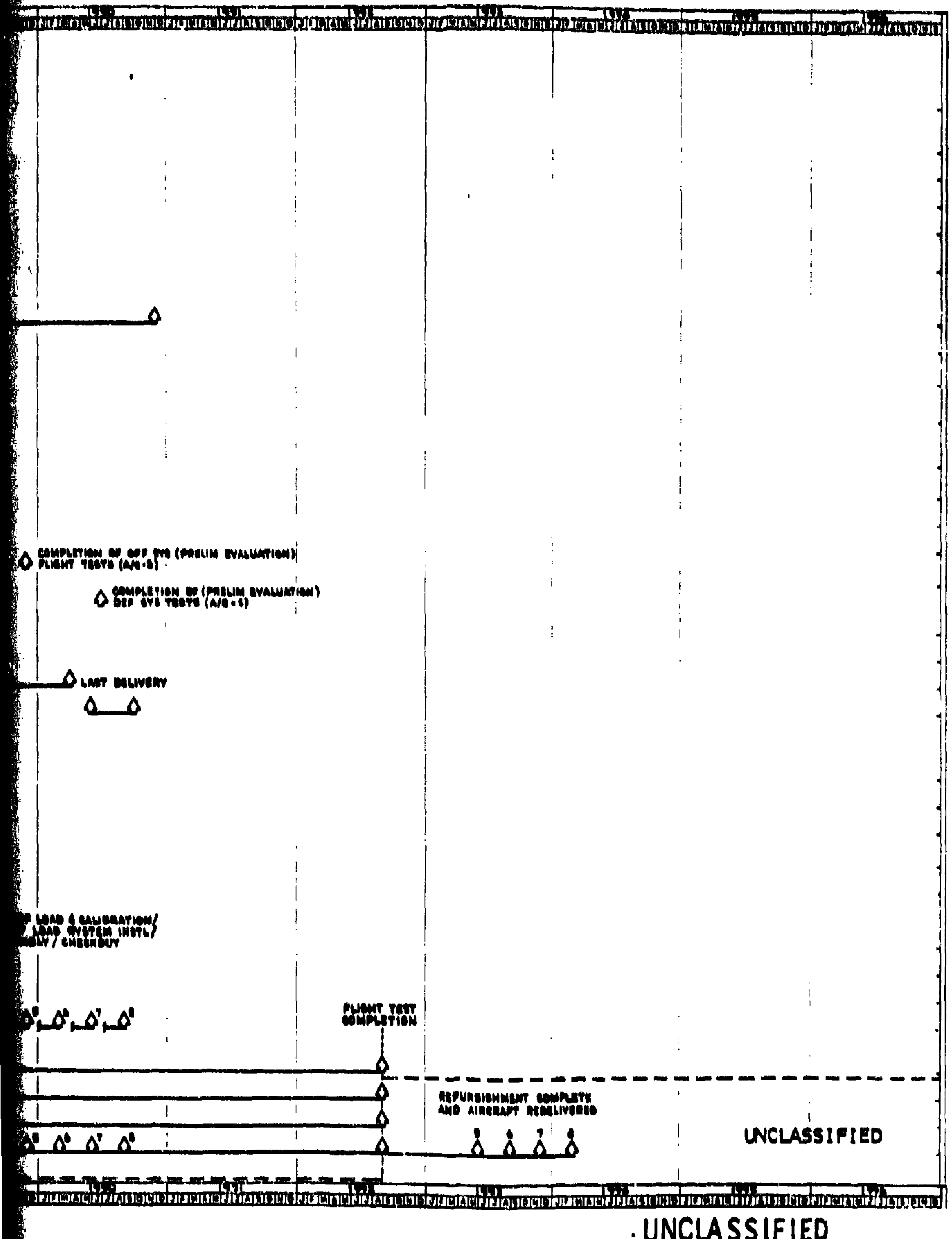

FIRST DELIVERY
LAST DELIVERY
UNCLASSIFIED
PRODUCTION
AIRCRAFT
DELIVERIES
MONTHLY
CUM
MONTHLY
CUM

2

(U) STEALTH CONCEPT (D645-4) MASTER PROG



GRAM SCHEDULE (RDT&E THRU PRODUCTION/DEPLOYMENT) (U)



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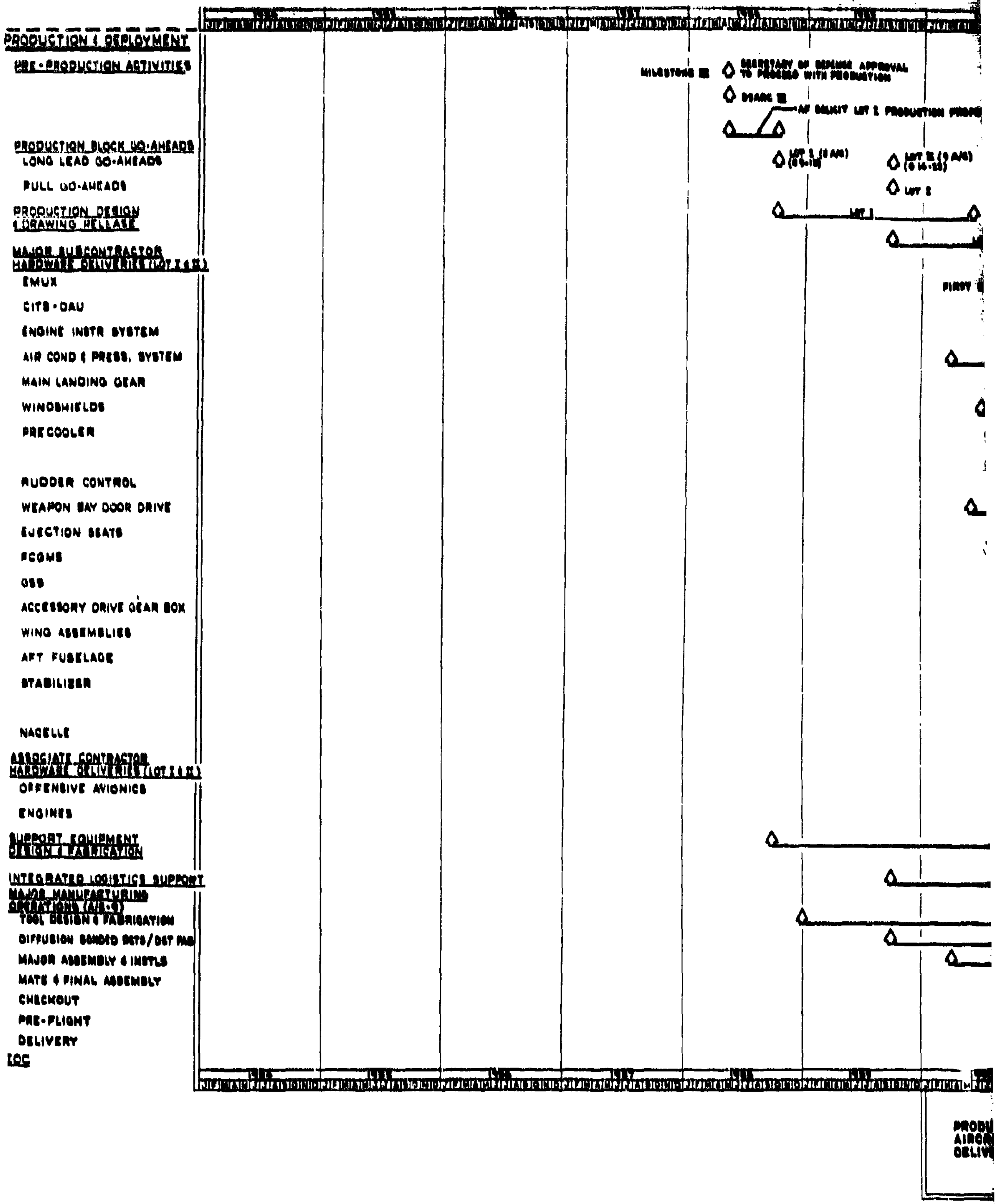
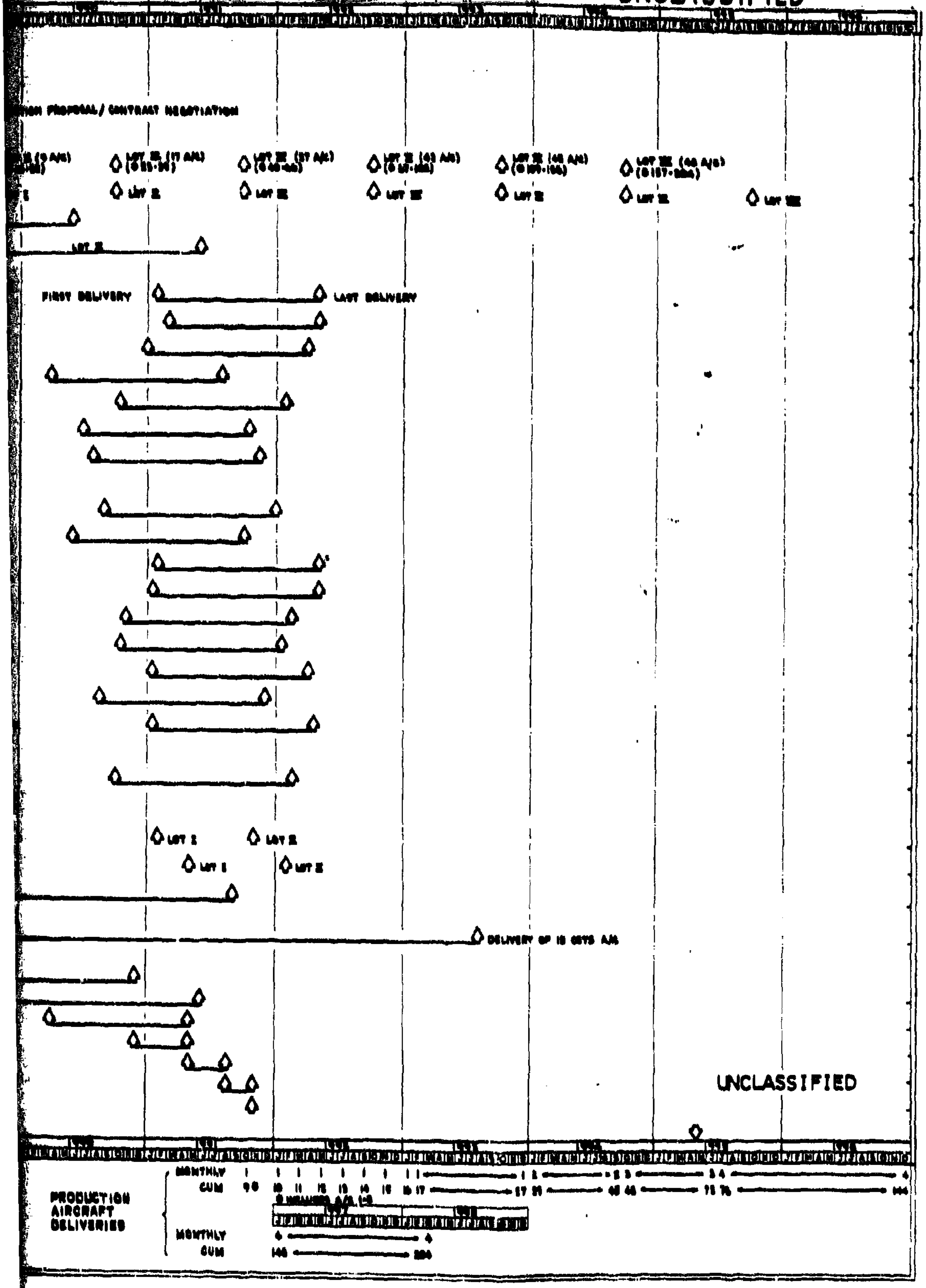
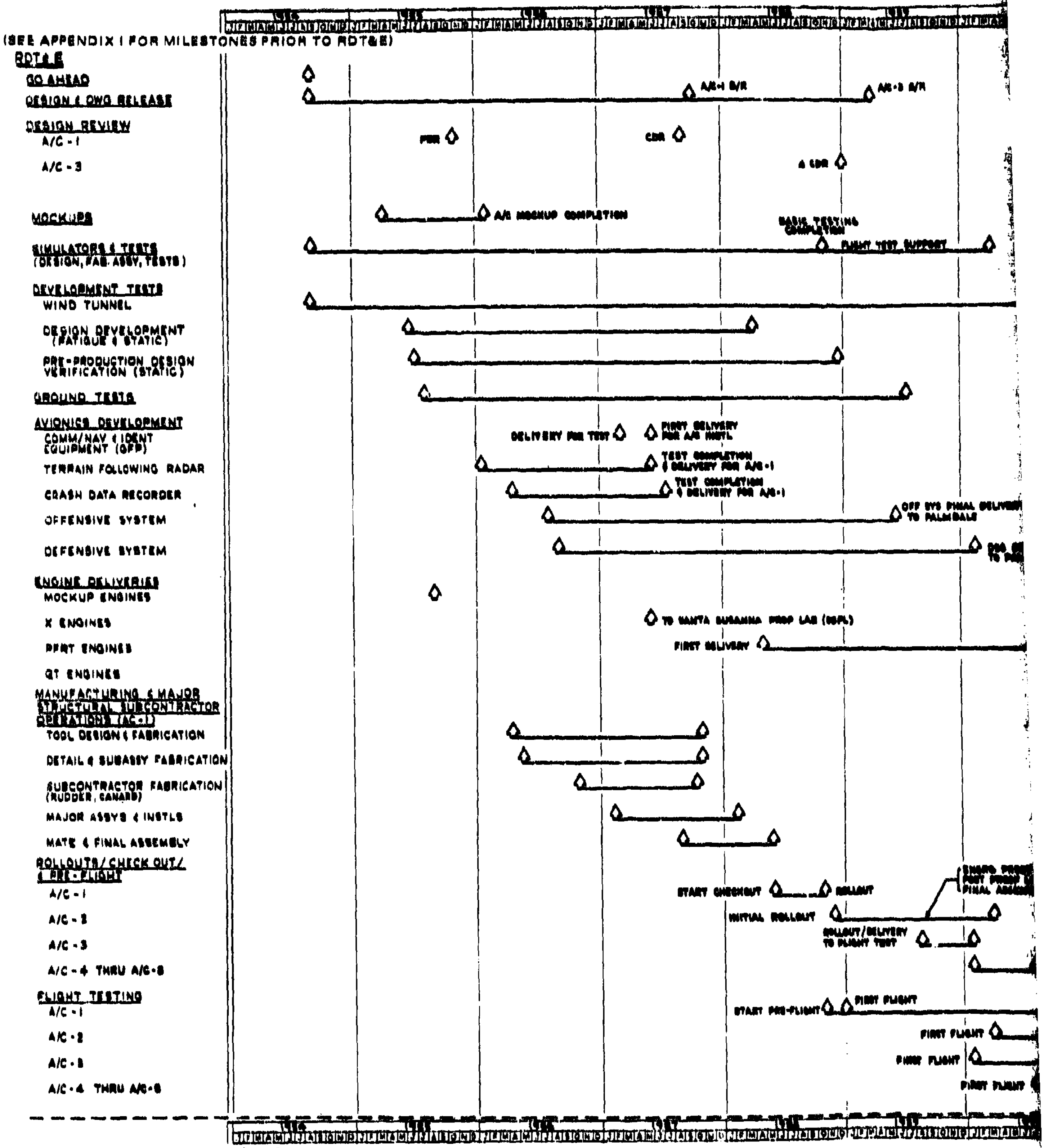


PRODUCTION & DEPLOYMENT
PRE-PRODUCTION ACTIVITIES
MILESTONE III
SECRETARY OF DEFENSE APPROVAL TO PROCEED WITH PRODUCTION
DSARC III
AF SOLICIT LOT I PRODUCTION PROPO
PRODUCTION BLOCK GO-AHEADS
LONG LEAD GO-AHEADS
FULL GO-AHEADS
LOT 2
PRODUCTION DESIGN & DRAWING RELEASE
LOT I
MAJOR SUBCONTRACTOR HARDWARE DELIVERIES (LOT I & II)
EMUX
CITS-DAU
ENGINE INSTR SYSTEM
AIR COND & PRESS. SYSTEM
MAIN LANDING GEAR
WINDSHIELDS
PRECOOLER
RUDDER CONTROL
WEAPON BAY DOOR DRIVE
EJECTION SEATS
FCGMS
OSS
ACCESSORY DRIVE GEAR BOX
WING ASSEMBLIES
AFT FUSELAGE
STABILIZER
NACELLE
ASSOCIATE CONTRACTOR HARDWARE DELIVERIES (LOT I & II)
OFFENSIVE AVIONICS
ENGINES
SUPPORT EQUIPMENT DESIGN & FABRICATION
INTEGRATED LOGISTICS SUPPORT
MAJOR MANUFACTURING OPERATIONS (A/C-6)
TOOL DESIGN & FABRICATION
DIFFUSION BONDED DETS/DET FAB
MAJOR ASSEMBLY & INSTLS
MATE & FINAL ASSEMBLY
CHECKOUT
PRE-FLIGHT
DELIVERY
IOC


FIRST DELIVERY
LAST DELIVERY
UNCLASSIFIED
PRODUCTION AIRCRAFT DELIVERIES
MONTHLY
CUM

(U) DEFENSIVE LASER CONCEPT (D645-5) MASTER



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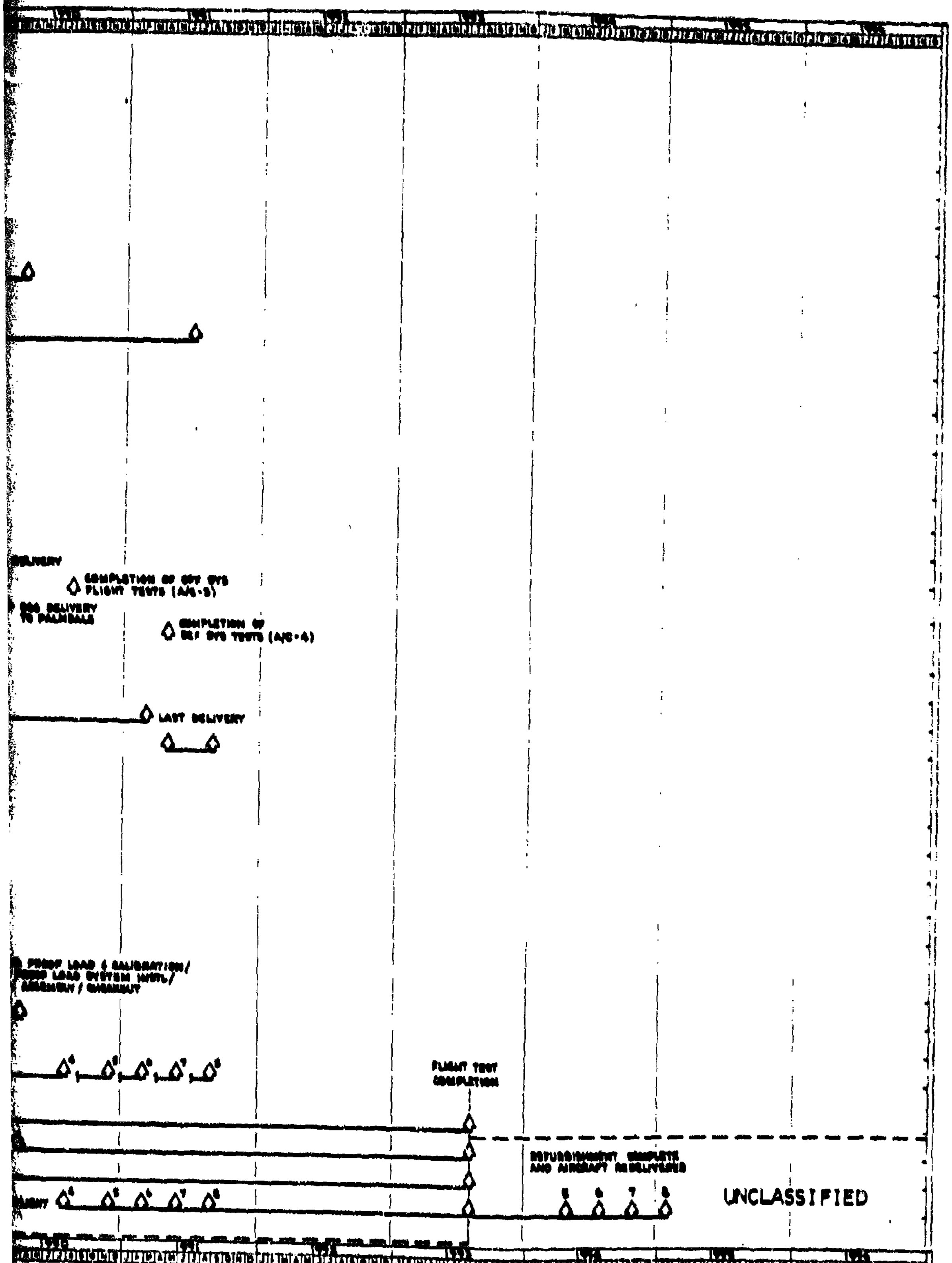
R PROGRAM SCHEDULE (RDT&E THRU PRODUCTION/DEPLOYMENT) (U)



UNCLASSIFIED

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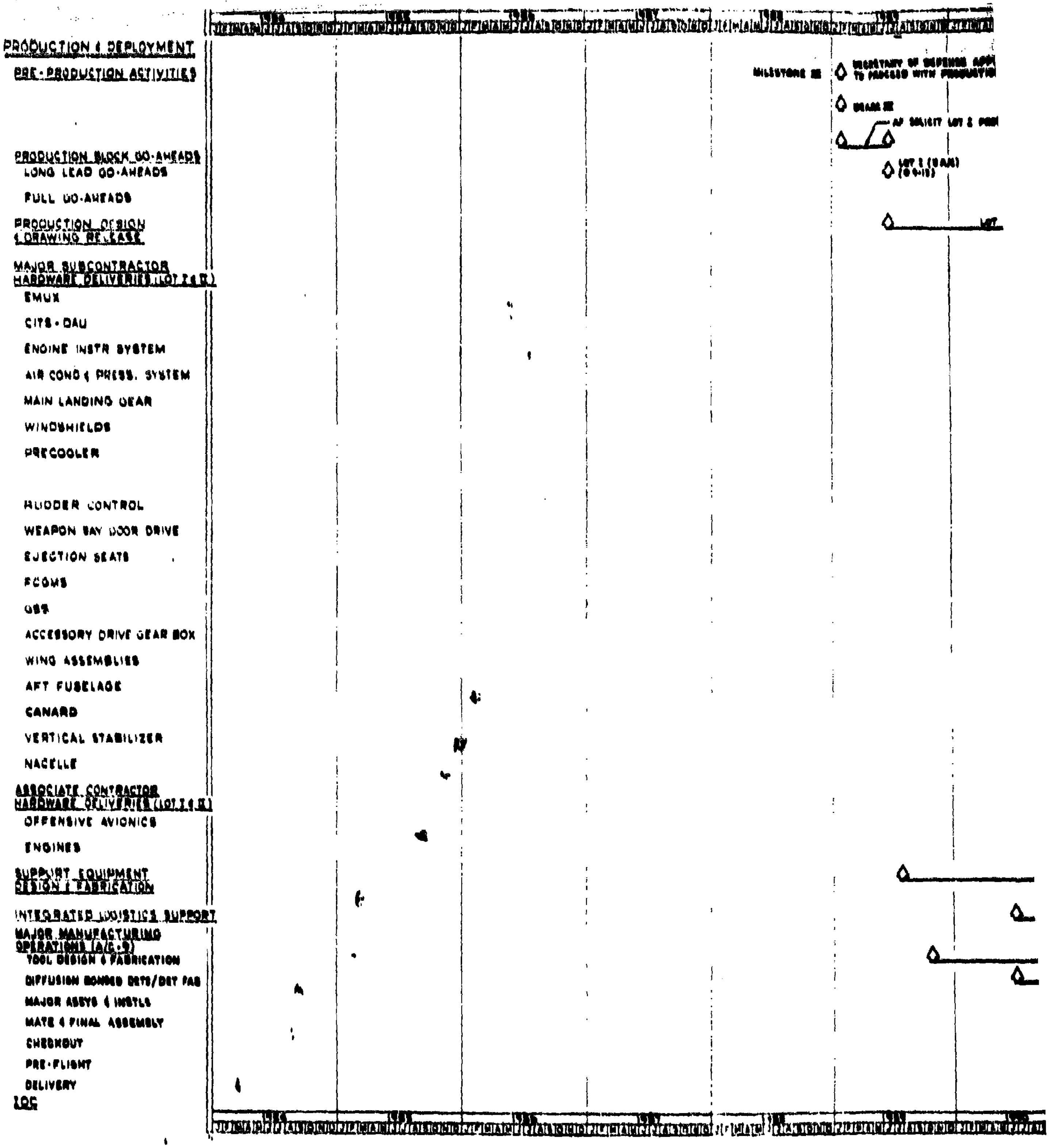
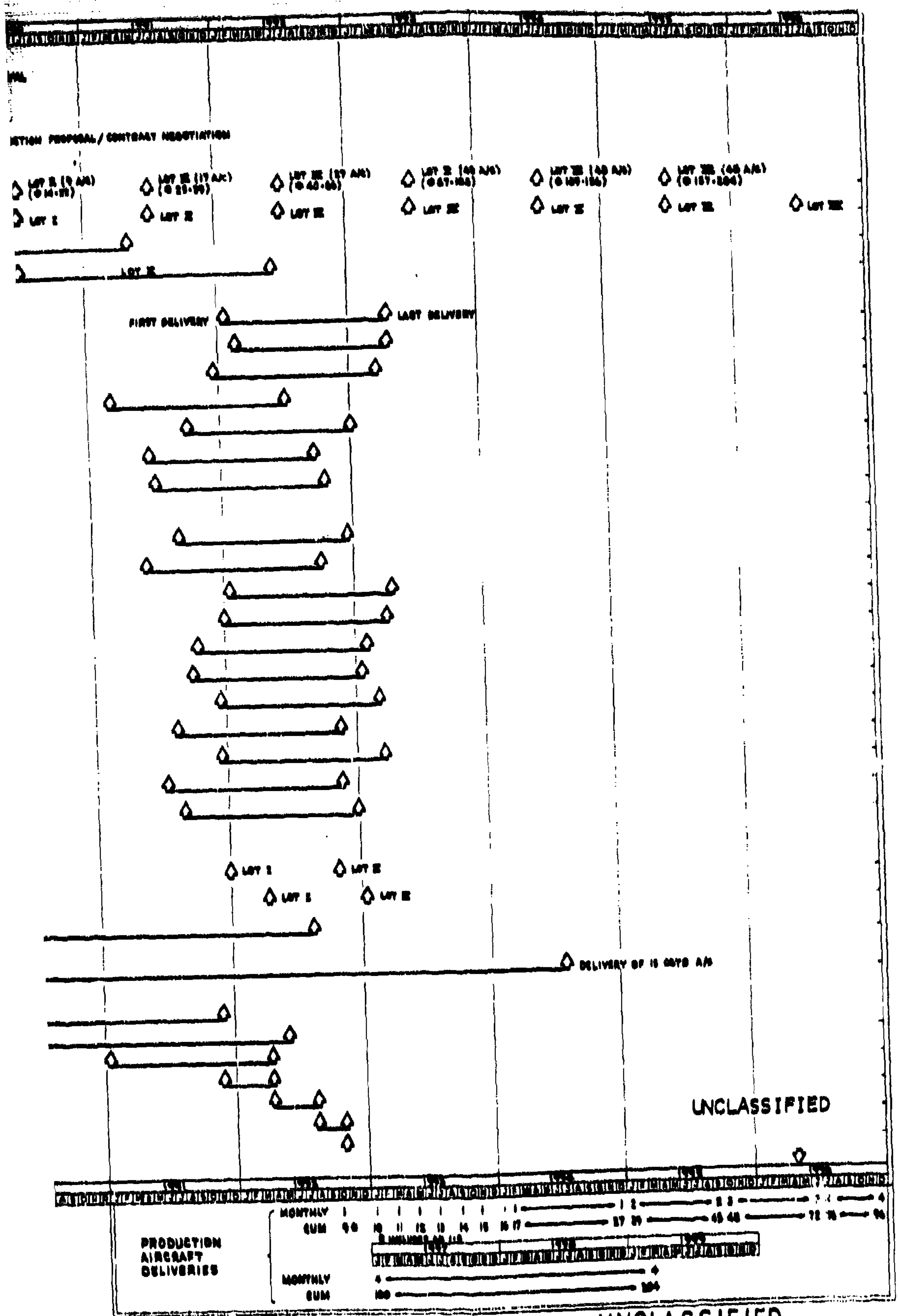

PRODUCTION & DEPLOYMENT
PRE-PRODUCTION ACTIVITIES
MILESTONE III
PRODUCTION BLOCK GO-AHEADS
LONG LEAD GO-AHEADS
FULL GO-AHEADS
PRODUCTION DESIGN & DRAWING RELEASE
MAJOR SUBCONTRACTOR HARDWARE DELIVERIES (LOT I & II)
EMUX
CITS - DAU
ENGINE INSTR SYSTEM
AIR COND & PRESS. SYSTEM
MAIN LANDING GEAR
WINDSHIELDS
PRECOOLER
RUDDER CONTROL
WEAPON BAY DOOR DRIVE
EJECTION SEATS
FCOMS
GSS
ACCESSORY DRIVE GEAR BOX
WING ASSEMBLIES
AFT FUSELAGE
CANARD
VERTICAL STABILIZER
NACELLE
ASSOCIATE CONTRACTOR HARDWARE DELIVERIES (LOT I & II)
OFFENSIVE AVIONICS
ENGINES
SUPPORT EQUIPMENT DESIGN & FABRICATION
INTEGRATED LOGISTICS SUPPORT
MAJOR MANUFACTURING OPERATIONS (A/C-9)
TOOL DESIGN & FABRICATION
DIFFUSION BONDED DETS/DET FAB
MAJOR ASSYS & INSTLS
MATE & FINAL ASSEMBLY
CHECKOUT
PRE-FLIGHT
DELIVERY
IOC


FIRST DELIVERY
LAST DELIVERY
UNCLASSIFIED
PRODUCTION AIRCRAFT DELIVERIES
MONTHLY
CUM
MONTHLY
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Appendix K

TASK SUMMARIES

For

High Priority Technologies for 1995 Strategic Aircraft

TASK SUMMARY, ADVANCED SUPERCRITICAL WINGS

DESCRIPTION

(U) Advanced Supercritical Wings will extrapolate current supercritical technology using advanced computational capabilities to provide reduced drag at high subsonic Mach numbers. These wings will be designed in three dimensions using transonic relaxation solutions to the small disturbance theory or full potential equations of motion. The resulting wing will be optimized such that the upper surface shock will be minimized, avoiding the pressure drag rise associated with shock strength.

REQUIREMENT

(U) Advanced Supercritical Wings were assumed for the ISADS baseline concepts because of the roughly 10% improvement in aerodynamic efficiency (ML/D) they provide. Other applications include all high speed cruising aircraft.

(U) Currently, supercritical technology is well documented in wind tunnel and flight test research for the airfoil technology. Analytical analysis techniques are available. The prime required advance is to extend these to 3-D design procedure and airplane synthesis. When this is accomplished, three-Dimensional wing design and optimization will provide nearly shock-free wings.

TECHNICAL APPROACH

(U) Ongoing research is developing the aerodynamic and computational technologies required for the development of advanced supercritical wings. Full 3-D wing design should be available in the 1990-2000 time frame.

FUNDING REQUIREMENTS

(U) A development cost of $10 million has been estimated.

TASK SUMMARY, LAMINAR SURFACE COATINGS

DESCRIPTION

(U) Laminar surface coatings are plastic coverings supplied over the aircraft skin which, by their smoothness, delay transition of the boundary layer. This reduces the skin friction drag yielding net cost and weight savings.

REQUIREMENT

(U) Laminar surface coatings realized an 8% reduction in take-off gross weight for the ISADS baselines. These coatings could be applicable to any aircraft. Currently this technology is being demonstrated on general aviation aircraft, and is commercially available. Application to large, high speed aircraft will require research to define the lightest and most durable coverings to use.

TECHNICAL APPROACH

(U) The basic concept of laminar surface coatings is proven. Research is needed to define the best coatings to use for large, high speed aircraft, and to wind tunnel and flight test the selected coatings. Laminar surface coatings could be available by 1985.

FUNDING REQUIREMENTS

(U) Development and test of laminar surface coatings for large, high speed aircraft should cost $3-5 million.

TASK SUMMARY, ACTIVE BOUNDARY LAYER SUCTION

DESCRIPTION

(U) Active boundary later suction involves mechanically removing the boundary layer off of the aircraft's skin by means of auxiliary pumps and ducting. This allows laminar flow, offering drag reduction yielding net weight and cost savings.

REQUIREMENT

(U) Application of laminar flow via active boundary layer suction to the ISADS baselines produced gross weight reductions of over 12% despite a conservatively assumed 10,000 lb dead weight penalty for pumps, ducts and wing redesign. Studies of cruise-only transport aircraft have shown even higher savings.

(U) Boundary layer suction has been verified in the X-21 flight research program conducted by Dr. W. Phenninger and his associates, as well as numerous wind tunnel programs. The primary difficulties remaining are the weight and operational penalties of the required ducts and pumps, and the solution to the ingestion problem.

TECHNICAL APPROACH

(U) The concept of active boundary layer suction is well established. The remaining technical effort should focus on structural concepts for minimizing the duct weight penalty, and investigation of ways to alleviate ingestion. Additional problems including moisture effects, allowable roughness, and leading edge instability require investigation. Active boundary layer suction could be available by the 1990's.

FUNDING REQUIREMENTS

(U) Recent estimates of funding requirements for the development of a feasible active boundary layer suction system have ranged from $100 to $200 million.

TASK SUMMARY, COMPOSITE PRIMARY STRUCTURES

DESCRIPTION

(U) Composite primary structure will apply composite materials, mostly graphite/epoxy, to the aircraft's major load carrying structures. This includes the wing box, fuselage, and tail surfaces. Major weight and cost savings will be realized, as well as making feasible such concepts as aero-elastic tailoring and forward swept wings.

REQUIREMENT

(U) The application of composite materials to the aircraft's primary structure yielded over 10% reductions in cost and take-off gross weight for the ISADS concepts. Currently, composites are seeing wide application in non-primary structures such as weapons bay doors and inlet ramps. Test articles of composite primary structures such as B1 tail surfaces have been fabricated and show 30-40% component cost and weight savings. These composite primary structures will be applied to all types of aircraft when problems such as fastening, weather and moisture effects, and bird or hail strike are resolved.

TECHNICAL APPROACH

(U) Ongoing research is pursuing the application of composite materials to primary structure. Application to production aircraft should be available in the 1985 to 1995 time frame.

FUNDING REQUIREMENTS

(U) Development of routine application of composite material to aircraft primary structure will require $200-300 million.

TASK SUMMARY, SPF/DB TITANIUM

DESCRIPTION

(U) Superplastic formed/diffusion bonded titanium is produced by forming multiple sheets of titanium under elevated temperatures and pressures, producing a single formed part featuring light weight and a high degree of geometric complexity. This allows fewer parts for reduced manufacturing costs.

REQUIREMENT

(U) The application of SPF/DB titanium to the hot parts of the ISADS concepts yielded approximately 2% reductions in take off gross weight, and a 3-5% reduction in cost. Currently SPF/DB titanium has been successfully used in portions of the B1 nacelles, and a B1 fuselage frame test specimen has been successfully fabricated and tested.

(U) SPF/DB titanium will see application in the nacelle area of most aircraft. Additionally, it offers a construction technique for aircraft skins with laminar flow ducts built right in.

TECHNICAL APPROACH

(U) Current research programs are developing the SPF/DB processes. The major program addressing them is the Built-Up Low Cost Advanced Titanium Structure (BLATS) program. This program will fabricate a main central selection of a representative fighter concept primarily out of SPF/DB titanium. This and other programs will make SPF/DB titanium available for large scale usage by the mid 1980's.

FUNDING REQUIREMENTS

(U) Further development of SPF/D titanium technology has been estimated at $10-20 million.

TASK SUMMARY, LAMINAR FLOW CONTROL STRUCTURES

DESCRIPTION

(U) Laminar flow control (LFC) structures are structures which inherently allow for laminar flow control ducting. LFC structures have ducting and surface porosity built in, thereby minimizing the weight penalty associated with laminar flow control.

REQUIREMENT

(U) The ISADS active boundary layer suction trade study showed a 12% reduction in take off gross weight, despite assuming a large weight penalty for laminar flow control pumps and ducts. LFC structure technology could yield another 10% reduction beyond this, by building the ducting and slots into the wing skin.

(U) LFC structures would find application on all range-dominated aircraft that could benefit from active boundary layer control.

TECHNICAL APPROACH

(U) The most promising approach for LFC structures is the use of Superplastic Formed/Diffusion Bonded (SPF/DB) titanium. This would enable ducts and slots to be formed into the wing skin in one process. SPF/DB titanium LFC structure should be available by the late 1980's.

(U) An alternate approach offering even greater weight savings is the use of SPF aluminum. This could allow LFC structure at virtually no weight penalty. SPF aluminum is not expected to mature until the late 1990's.

FUNDING REQUIREMENTS

(U) Application of SPF/DB titanium to produce LFC structures should cost approximately $10 million.

TASK SUMMARY, ADVANCED AFTERBURNING TURBOFAN

DESCRIPTION

(U) Controlled evolution rather than revolution is forseen in propulsion. Engine thrust-to-weight ratios as high as twelve are projected based on improvements in overall pressure ratio, component aerodynamics and materials, and augmentor efficiencies. Variable cycle will be available for aircraft encountering widely different flight conditions, but cost is expected to keep application to extreme cases.

REQUIREMENT

(U) The ISADS study indicated approximately a 15% reduction in take-off gross weight due to these improvements over current engines. This general improvement in the propulsion state of the art will be applicable to all aircraft, with availability in the 1990's.

TECHNICAL APPROACH

(U) Currently planned research will bring about these advances. This research will be directed in several areas.

(U) Compressors will be improved by the use of 3-D flow analysis programs capable of design as well as analysis. Centrifugal compressors may be in incorporated, contributing to reduced cost as well as higher pressure ratios.

(U) Combustors and turbines will also be improved by the use of 3-D flow analysis and design programs. Additionally, improved materials such as ceramics will permit much higher operating temperatures.

(U) Augmentors will yield higher efficiencies with less weight and bulk by the use of swirl can burners.

FUNDING REQUIREMENTS

(U) Overall propulsion development costs will be on the order of $100 million to $1 billion.

TASK SUMMARY, ACTIVE CONTROLS

DESCRIPTION

(U) The specific active controls technologies identified as high priority for the ISADS concepts are relaxed static stability, maneuver load control, and structural mode control. All depends on the use of fly-by-wire technology, which is now considered state of the art.

(U) Relaxed static stability uses automatic longitudinal feedback controls to augment the aircraft stability. This allows a smaller horizontal tail, a further aft center-of-gravity, and hence reduced drag and weight.

(U) Maneuver load control reduces structural weight by automatically unloading the wingtips in a turn or pullup. This allows reduced structural load factor margins, which reduce structural weight.

(U) Structural mode control uses aerodynamic controls to damp out structural bending modes. This reduces the excess structural weight required solely to meet stiffness criteria.

REQUIREMENT

(U) The ISADS study indicated approximately 5% gross weight reductions due to relaxed static stability, 7% reduction due to maneuver load control, and 8% reduction due to structural mode control. Active control technology is considered near term, with the required fly-by-wire and digital avionics capabilities considered current state of the art. Active control technology will be be applicable to virtually all high-technology aircraft.

TECHNICAL APPROACH

(U) Required research for the implementation of active controls is well under way. Relaxed static stability and structural mode control have been demonstrated in the F-16 and B1 (respectively), and maneuver load control will be featured on the next version of the L1011. All will be considered routine state of the art by 1985.

FUNDING REQUIREMENTS

(U) Approximately $8 million will be spent perfecting active controls technology in the next five years.

TASK SUMMARY, STEALTH TECHNOLOGIES

DESCRIPTION

(U) Stealth technologies increase an aircraft's survivability by reducing the probability of its detection by opposing forces. Stealth technologies considered essential to the ISADS stealth concept are radar absorbent materials (RAM), radar reflective flashed glass canopy, tuned randome and cooled plug nozzle.

(U) Radar absorbent materials (RAM) are dielectric materials into which electrically active elements are positioned which absorb radar energy. These RAM materials may be either applied as a coating over existing structure, or built as structural RAM which can replace existing structure.

(U) The radar signature caused by the cockpit cavity is reduced by flashing the canopy glass with metal, usually gold. This makes the glass radar reflective so that the inside cockpit cavity is not encountered by the radar energy.

(U) In similar fashion, the randome cavity signature is reduced by adding a slotted metallic foil which allows only the frequency of the aircraft's radar to pass. For all other frequencies, this "tuned" radome appears solid, eliminating the radome cavity signature.

(U) Cooled plug nozzles reduce infrared signature by cooling the exhaust flow and shielding the hot parts. In addition, proper shaping can reduce radar signature by hiding the rear engine face.

REQUIREMENT

(U) These stealth technologies were considered essential to the ISADS stealth concept because they offer significant reductions in the probability of detection. This in turn increases the aircraft's probability of survival.

TECHNICAL APPROACH

(U) The greatest improvement needed in RAM is an increase in the frequency range of the highly absorbent types of RAM. In addition, RAM materials must be developed to withstand high temperatures. This will allow radar absorbing nozzle structures.

(U) Gold-flashed canopies are current state of the art. Additional research should address reductions in cost and the loss of optical transmissivity caused by the flashing.

(U) Ongoing research is developing both the tuned radome and cooled plug nozzle, with availability expected in the 1990's.

FUNDING REQUIREMENTS

(U) Total funding requirements for these stealth technologies is estimated on the order of $100 million.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 88TH AIR BASE WING (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE OHIO

9 Jan 2008

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3810 Communications Blvd
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Defense Technical Information Center
Attn: Ms. Kelly Akers (DTIC-R)
8725 John J. Kingman Rd, Suite 0944
Ft Belvoir VA 22060-6218

Dear Ms. Akers

This concerns Technical Report ADC016293, Innovative Strategic Aircraft Design Study (ISADS) Phase 1 – Jun 1978,

Subsequent to WPAFB FOIA Control Number 07-153LK, the distribution statement: "Distribution authorized to U.S. Vog't agencies and their contractors; Specific Authority; May 78. Other requests must be referred to Commander, Aeronautical Systesm Div., Attn: XRT, WPAFB **is no longer applicable to this document**.

The document has was reviewed by the SAF/AQL, Col Roger M. Vincent, Director, Special Programs, and it has been determined that the distribution statement should be changed to statement A (publicly releasable). (see attached 27 Nov 2007 memorandum) The record is fully releasable to the public.

Point of contact is Lynn Kane at (937) 522-3091.

Sincerely

LYNN KANE
Freedom of Information Act Analyst
Management Services Branch
Base Information Management Division

Attachments
1. Copy of SAF/AQL Memorandum
2. Cover sheets of ADC016293
3. Full Citation of ADC016293
4. FOIA Request