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COMPUTERIZED PRELIMINARY DESIGN AT THE EARLY STAGES OF VEHICLE DEFINITION

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INTRODUCTION

The preliminary design process, if used effectively, can save aircraft system costs during the development, acquisition and operation of future vehicles. The key to this saving is adequate exploration of the many suggested design approaches offered during the early definition of the vehicle concepts and the selection for further study of those concepts that indicate significant saving. In many cases, promising approaches are discarded prematurely because there are not sufficient resources to investigate very many of these approaches. Instead, there is a tendency to focus on the most conventional approach as a baseline and then to increase the design effort on this concept (or minor derivatives) to provide confidence in the approach. The result is a credible but unimaginative design that does not indicate the potential of other approaches.

How can this common occurrence in the early design process be avoided when the resources available for the conceptual and preliminary design phases are limited? One distinct possibility is to increase the efficiency of the design process at these early stages by the use of computerized and automatic methods. Design concepts can then be evaluated rapidly using accepted engineering computation methods. A considerable quantity of valid information from this process can then be used to help select the most promising concepts for additional study and design.

COMPUTERIZED PRELIMINARY DESIGN AT THE EARLY STAGES OF VEHICLE DEFINITION

By Thomas J. Gregory*

ABSTRACT

The conceptual and preliminary design processes are used to provide information regarding the feasibility and selection of various approaches to aircraft mission requirements. Decisions influenced by this information often have enormous cost implications at the later stages of the development process and during vehicle operation. Yet, the resources expended during the early phases are usually relatively small and distributed over several alternate approaches. The information provided during these early conceptual and preliminary design phases needs to be credible and complete, however it must be generated with limited resources. This paper describes criteria for acceptance of early design information, modern methods of providing it and suggestions for defining adequate levels of resources to accomplish the objectives of the activity. Specific examples of the most difficult type of early design studies, those requiring significant undeveloped technology, are used to discuss these points. The examples include design studies and cost estimates of liquid hydrogen fueled aircraft, oblique winged aircraft and remotely piloted vehicles.

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Most agencies and companies have developed computerized tools for preliminary and conceptual design (refs. 1-9), and these programs have been used to a large extent in recent years in providing information for future vehicle concepts (refs. 10-14). These programs usually take the form shown on the first figure which indicates the individual disciplines required in the aircraft early design process. In each discipline the design function is mathematically modeled to an appropriate level and the results integrated to provide a vehicle definition for a specific mission. This general arrangement is common to many of the programs, but the method of interconnection, the level of detail and the emphasis on particular aircraft types distinguishes between these programs. The NASA-Ames Research Center aircraft synthesis program, called ACSYNT, uses the common arrangement shown in the figure and will be used here to help describe the general features in computerized preliminary design programs and the trends toward improving their usefulness, efficiency and credibility. Suggestions are offered regarding the approximate level of resources required to develop and utilize these types of programs.

DESIGN LEVELS

Prior to describing the characteristics of the computerized preliminary design process, it is important to understand the objective and scope of the activities at the early stages of vehicle definition. The primary purpose at these levels is to provide technical and economic feasibility information for guiding larger efforts during the detailed design phases. It is important to realize this purpose and not confuse it with the detailed or final design process where the objective is to provide enough information to actually build the vehicle or to develop a careful plan to build it. In order to help define the appropriate level of detail to meet the objectives at the early design stages, figure 2 shows the definition, used at NASA-Ames, of four design levels in aircraft development.

The conceptual level is characterized as the idea stage where form, connectivity, component placement and approximate size are defined. At this stage, limited engineering calculations are performed to provide a three-view drawing and cross sections showing approximate placement and size of all the major vehicle components. An equally important output is a list of attributes based on physical principles that suggest the reasons this system has potential. This list and the physical principles help the advocate of an idea to define the source and limits of the potential improvements that are expected from his idea. This stage usually requires little resources and yet is a primary source of ideas. Significantly increased resources are needed to evaluate these ideas and compare them with other approaches. Emphasis in the conceptual stage is on clear definition of the idea and the theoretical or empirical basis for suggesting why the concept has merit. Little emphasis or reliance is placed on the simplified and isolated computations that may suggest what the quantitative performance of the concept is.

The next design level, preliminary design, attempts to evaluate these concepts with simplified and rapid engineering computations in a balanced effort. At this point, the emphasis is on the quantitative measures of performance in order to make comparisons. These computations can use standard methods of analysis and rely on historical correlations for validity. However, with concepts that are novel or unusual, the existing engineering approaches may not be well suited, especially when they rely on empirical approaches that do not match the study concept closely. Under these circumstances, significant theoretical study is required to validate the performance of the design. This is a key area that will be discussed later in describing the resources needed in the computerized design process.

The figure indicates that the output from the preliminary design process provides, again, a three-view drawing showing computed shape, size and connectivity as well as computed multi-element weight and cost statements. The results also include description of the computed aerodynamic, structural and propulsive performance parameters. Note the emphasis is on computation of the results, since this quantified information is used to compare with other results in the selection process. This level of design usually relys entirely on analytical calculations (both theoretical and empirical), however, these need to be based on experimental correlations and information from past or current experimental research programs. In the preliminary design stages as defined here, no experimental work is directed to design verification. This work is left for the detailed design stage.

Figure 2 indicates that the detailed design stage emphasizes accurate and detailed investigation of a fixed configuration but does include tradeoff studies to improve and refine the vehicle performance.

Major design concept changes usually are not permitted unless conducted in parallel detailed studies. This level of design usually is augmented by experimental verification in the aerodynamic and possibly critical structural areas. The major output of this activity is the detailed assembly drawings with specific definition of the major components and a careful plan indicating the schedule and resources required for the development, acquisition and operation of the vehicle.

In the final design level, the objective is to provide the component and assembly drawings for construction of the vehicle. An integrated computerized process to perform this activity has been studied (refs. 15 and 16), but has not been implemented. Of course, mechanized drafting and preparation of tapes for numerically controlled tools is done at present on a nonintegrated or isolated basis. These functions are key elements in automated design that may be expected to evolve into integrated final designs in the future.

PRELIMINARY DESIGN STUDY REQUIREMENTS

The focus of this paper is on the conceptual and/or preliminary design level and not the detailed and final design level as defined above. What are the requirements for effective computerized conceptual and preliminary designs at these early stages of vehicle definition? Figure 3 indicates the main features or characteristics found in these programs. First the programs usually are extremely modular so that the functions to be performed are clearly separated and can be assembled to perform various sequences of computations depending on the problem.

Modularity is very important since each module of a synthesis program should be verified on an individual basis prior to integration with others. Modularity also greatly simplifies data transfer and error identification during program development and operation. Each module provides the intermediate data from a particular discipline that is required by other modules as well as the final data from that discipline that is needed for adequate vehicle definition.

The concept of extreme modularity actually leads to more simplification in obtaining a truly integrated design procedure. A control program is used to exercise the individual modules and the data from these modules is transferred to other modules for additional computations. In many computerized design processes, transfer of input and output between programs (integration) is not well developed and in some cases is performed manually. Integration of the individual modules that make up a program can be accomplished in either of two ways. First, it is possible to connect the basic analytical modules that estimate the information in a particular discipline; for example, aerodynamic modules may compute lift and drag directly from vehicle geometry. Another method is to use these modules on an isolated basis to develop scaling information for estimating changes in a precomputed baseline concept. In most bases, the scaling programs can be considerably simplified and require minimum resources to develop or operate. However, the resources necessary to perform the baseline design and then develop the scaling relationships are the major part of the whole effort. The total resources, both engineering man-hours and computer time, necessary to perform a design using the scaling approach actually is comparable to the direct method. In addition, the scaling relationships usually are simplified by omitting parameters of secondary importance, whereas direct use of basic modules to compute performance in each discipline assures the incorporation of all parameter effects as accurately as they are being modeled.

Design programs that use scaling information are well suited to computations in the later stages of design where computations in each of the disciplines becomes much more detailed and time consuming, and yet updates on the configuration design are required on an almost continuous basis. However, at the early stages of preliminary design, direct transfer of information between programs that provide basic data can be a more flexible and usable approach that the use of scaling programs.

Another characteristic of aircraft synthesis programs is the capability to provide calculations at different levels of detail. Simplified computations are required to estimate the initial characteristics of the vehicle so that more detailed computations in each discipline area can proceed. In an efficient integrated program the selection of the appropriate levels is under control of the designer. At Ames Research Center these design levels are characterized by the descriptions given in figure 4. Note that at each level there is sufficient information for a completed design in terms of the quantitative measures indicated earlier. The primary reason for increased level of detail is to incorporate more credible methods. The computation time and cycle time required to complete a vehicle design increases significantly with the level of detail in the computations. Since a major requirement in preliminary design is the assessment of many ideas that have been selected for study, it is particularly important that these alternate approaches be compared rapidly. A guideline for the development of the NASA-Ames ACSYNT program is that a vehicle analysis in Level I requires less than 1 minute of computer time (IBM 360/67) and that Level II requires less than 5 minutes. A vehicle studied to design convergence usually requires 2 to 5 vehicle analyses. Design convergence means that the vehicle performs the specified mission within a stated tolerance and that all computations are performed on essentially the correct configuration geometry and weight. Unless design convergence is accomplished, results for different approaches cannot be compared closely.

An important required output in the computerized preliminary design process is sensitivity information that permits an assessment of critical areas. Extreme sensitivity can lead to discarding a design or indicate the need for technology improvement before the design can be considered feasible. The next figure (fig. 5) shows an example of the sensitivity information provided by the ACSYNT program during the assessment of an oblique winged transonic transport at Ames Research Center. The oblique winged airplane (ref. 17) is a unique approach to high aerodynamic efficiency at cruise and good low-speed characteristics. Sensitivity is defined as the percentage change in a performance measure due to a percentage change in the parameter. For example, the percent change in gross weight due to a percent change in a mission or a vehicle parameter. There are three categories of parameters for which sensitivity information is usually desired. The first category includes the mission parameters such as range, payload, turn rates, endurance, etc. The second includes the vehicle design parameters such as wing loading, wing aspect ratio, body fineness ratio, etc. The third category includes the efficiency parameters such as engine compressor efficiency, span load efficiency, minimum drag coefficient, etc.

Sensitivity to mission parameters indicates the ease or difficulty that the general concept has in performing the specified mission, i.e. feasibility. Sensitivity to parameters in the second category provides information for optimizing the vehicle, since this is essentially gradient information indicating the direction of improved performance measure.

Sensitivity information from the third category is used to identify overall improvement in the vehicle due to changes in the technology of a specific area. This type of information helps focus research on the most significant areas.

Sensitivities which can be provided automatically by the ACSYNT program are difficult to obtain in manual design processes and therefore usually are not provided. In computerized early design they are readily computed and should be required as part of the study results.

Another important requirement in computerized preliminary design is the need to provide optimization and tradeoff type calculations that result in the best performance for a vehicle concept. The next figure (fig. 6) shows the results of an automatic seven parameter search for a minimum gross weight airplane design to perform a remotely piloted research vehicle mission. This remotely piloted vehicle was constrained to a specified level of performance in terms of sustained turn rates at two different Mach numbers and altitude conditions. The optimization process selected the best combination of wing area, sweep, thickness ratio, taper ratio, vehicle thrust-to-weight ratio, body diameter, and body fineness ratio to perform the mission with its constraints. Note that the design variables did not change significantly, yet the vehicle weight changed by 27 percent. Unless these types of optimizations are performed, the study concepts have poorer performance than necessary which makes comparisons less valid. The code to perform this constrained minimization (CONMIN, ref. 8) has been applied to many different types of engineering computations, and is useful in suboptimization in the individual discipline modules.

Another example of the use of the optimization process is shown in the next figure (fig. 7) in which a liquid-hydrogen-fueled hypersonic aircraft was optimized for maximum passenger load by changing the geometric characteristics of the vehicle (ref. 11). The vehicle propulsion system also was optimized automatically, and in this case the use of an automatic procedure was extremely important, since the problem complexity would have required considerable engineering time to resolve by manual methods. Here, the propulsion system consisted of three engines; a ramjet, turbojet and rocket and the problem was to maximize the passenger load subject to a sonic boom constraint. Optimization was accomplished by manipulating the size of each of the three propulsion systems, which operated simultaneously in the transonic region, and determining the appropriate time for the rocket to ignite and shutdown. This optimization permitted the computation of maximum passenger loads for a given gross weight vehicle as a function of sonic boom constraint as shown in the figure. For unusual aircraft concepts such as in this example, it is very difficult to select combinations of design parameters on intuition, and therefore automated optimization is essential.

CRITERIA FOR PRELIMINARY DESIGN INFORMATION

The computerized preliminary design process should include the information described earlier, that is, final information from each of the discipline areas at various levels of detail, sensitivity of the vehicle to mission and vehicle parameters, and optimization of the vehicle geometry and design parameters. In addition, these results should be presented so that the user has an assessment of the accuracy and the credibility of the information. An effective means of providing this credibility is to show the results in combination with correlation attempts in the individual module or discipline areas. For example, in the aerodynamics area, correlations between the analytical results and experimental data should be provided as part of the preliminary design process output. The next figure (fig. 8) shows the correlation of the estimated high angle of attack aerodynamic characteristics as predicted by analytical methods, and also shows a comparison with experimental results from a study aircraft. These comparisons can be used to provide statistical information regarding standard deviations and probable errors that indicate the accuracy expected from each of the discipline areas. This accuracy information, when combined with the sensitivity information described earlier, gives an overall assessment of the accuracy of the results of the studies. For example, if the probable error in estimating drag at high lift is 10 percent and the vehicle weight sensitivity to this parameter is 0.7, then the probable error in gross weight due to drag at high lift is 7 percent. This type of information should be provided routinely to the users of preliminary design results so that they are not mislead by small differences between alternate design concepts.

An additional means of providing credibility for the computerized design process is to compare the total integrated computation results for a specified mission with an actual aircraft designed for that mission. The next figure (fig. 9) shows the results of a comparison between the ACSYNT program and a Boeing 727-200 aircraft. In this case, the inputs to the ACSYNT program were the seating arrangement, the wing, body and tail geometry; and the engine characteristics in terms of design bypass ratio, pressure ratios, turbine inlet temperature, etc., and one-dimensional cycle efficiency parameters for the engine components. The results indicate adequate correlation in terms of the geometry and total weight of the system; however, individual elements in the weight statement do not agree well and suggest that further investigation is required. It is necessary to continually perform these correlations at the total aircraft level to check the analytical methods, since they are under continuous development or enhancement. The results of these correlation studies or their references should be included as part of any preliminary design study.

RESOURCES REQUIRED IN COMPUTERIZED PRELIMINARY AIRCRAFT DESIGN

The resources needed to perform the computerized process at the early stages of vehicle definition are primarily engineering man-hours and computer time. By far, the most costly and important resource expended during this process is engineering time, even when the process is highly automated. Engineering time is usually divided between program development or modification and the preparation and analysis of input and output data.

The development and modification of modules to compute design information in the various disciplines has been underway for several years and in many cases the modules or methods are available. However, most of these modules require continual enhancement and further development to apply them to the variety of concepts studied in preliminary design. Unusual or unique design require the development or modification of existing methods to provide good results. An example is the oblique winged aircraft that was mentioned earlier. This vehicle (fig. 10) operates with increasing wing sweep as speed increases and the changing geometry and antisymmetry of the configuration required significant modification to existing aerodynamic modules.

The next figure (fig. 11) shows a liquid hydrogen fueled aircraft (ref. 10) with a tankage arrangement that had no historical counterpart or empirical data base and hence required the development of specialized theoretical computer programs to investigate the structure. The tanks in the vehicle support all the vehicle loads and are pressurized. These examples of unique or unusual configurations indicate that a majority of the resources necessary to perform computerized preliminary design are spent in the investigation of unusual or unique features. Conventional design features can be studied with existing modules in many cases.

At the present time considerable resources are spent during computerized preliminary design in the preparation of input and output information. This is an area that can be made much more efficient. Digital computer technology to automate the input data function and to display engineering results has reached a mature point of development and should be included in efficient preliminary computerized design processes. Computer terminal hardware (fig. 12), which may be located directly in the preliminary design work area, consists of cathode ray tube devices for display of the information and input devices of various forms including keyboards and digitizing electrical tablets. In the last few years the price of these devices has been reduced significantly and they can be connected to large-scale computers through telephone or data communication networks. The key element in the use of these devices is the time-shared operation of the main computer which permits access to substantial computer resources without committing the computer and its expense during periods of no computation. The software to support these types of computer systems is substantial, but has been undergoing development and enhancement for several years. At the present time these systems are operational and performing satisfactorily, although the rate of technological progress (and obsolescence) is relatively high.

The figure shows the computer terminals at NASA-Ames that connect to a time-shared central computer with sufficient power to perform large-scale engineering computations (ref. 18). The vehicle geometry displayed on the tube was defined from the tablet and sketch shown in figure 12. The output of configuration drawings (fig. 13) and engineering results (fig. 14) from this equipment is suitable for inclusion directly in publications and the generation of the information is becoming automatic.

The resources and time needed to initiate or expand a preliminary design activity to the point described in this paper are significant. The modules used in the ACSYNT program represent more than 100 man-years of development and enhancement over a period of more than 10 years. The program is capable of analyzing conventional transport and fighter type aircraft, but is still in a state of rapid evolution as new capabilities and theoretical methods are continually incorporated.

The specialized personnel needed to integrate and develop the programs to perform this type of design activity are the major factor in the success of the activity. Each of the technical discipline areas is complex and the development and use of efficient programs in these areas requires the dedication and skill of technical experts. Professional engineers and scientists with proper training are needed to insure that the methods and correlations required in the preliminary design activity are sound. Attempts to center these activities around personnel skilled only in computer programming have not been effective. It also should be pointed out that it is difficult to pursue this process on an ad hoc or part-time basis, since as stated before, continuous development and correlations between analytical methods and experimental information are required. The high growth rate in computer technology has permitted a corresponding improvement rate in the analytical methods used to perform preliminary design. Hence, the development of new analytical methods and the obsolescence rate of old ones is sufficiently great to require the continued attention of professional specialists.

Once an operational capability as described above has been achieved, the computerized preliminary design of new but relatively conventional concepts is anticipated to require only modest resources and time. The goal for the ACSYNT program is to provide all the results described earlier (including optimization and sensitivities) for a single vehicle in less than one week at Level I and less than one month at Level II. Approximately six professionals and two hours per day of computer time are anticipated during the activity. Of course the objective in early design studies is to compare many approaches. If several aircraft concepts with similar missions and features are studied, then the computerized design process can investigate several vehicles much more readily than manual methods can. The advantage depends on the similarity of the vehicles and their components.

SUMMARY

The computerized preliminary design process can provide significant information that may influence the future costs of aircraft development and operation. This information can guide the design process toward concepts that have significant promise. The early study results can be based on established engineering methods that are adapted for computerized techniques and integrated for rapid use. The preliminary design process needs to be rapid and efficient in order to provide enough credible information to make sufficient comparisons. The results should include correlations with existing experimental data and should provide optimization and sensitivity information.

The primary resource required to perform this activity is engineering time which is best directed toward the development of methods and the analysis of unique concepts. The preparation of input data and the manipulation of output information for rapid review and analysis should be highly automated. The computer technology is available to modernize and automate much of this early design activity, but the total process is still entirely dependent on professional specialists using the most modern methods and equipment.

REFERENCES

1. Boyles, Richard Q.: Aircraft Design Augmented by a Man-Computer Graphic System. J. Aircraft, Vol. 5, No. 5, October 1968.

2. Lee, Vernon A.; Ball, H. Glenn, Wadsworth, E.A.; Moran, W.J.; and McLeod, J.D.: Computerized Aircraft Synthesis. J. Aircraft, Vol. 4, No. 5, Oct. 1967.

3. Gregory, Thomas J.; Petersen, Richard H.; and Wyss, John A.: Performance Tradeoffs and Research Problems for Hypersonic Transports. J. Aircraft, Vol. 2, No. 4, August 1965.

4. Williams, Louis J.: Transonic Transport Study - Summary. NASA TM X-62,156, May 1972.

5. Baals, Donald D.; Robins, A. Warner; and Harris, Roy V., Jr.: Aerodynamic Design Integration of Supersonic Aircraft. J. Aircraft, Vol. 7, No. 5, October 1970.

6. Hague, D.S.; and Glatt, C.R.: Optimal Design Integration of Military Flight Vehicles - ODIN/MFV -. Technical Report AFFDL-TR; 72-132, Dec. 1972.

7. Schuberth, E.R.; and Celniker, Leo: Synthesizing Aircraft Design. J. Space/Aeronautics, April 1969.

8. Wallace, R.E.: Parametric and Optimization Techniques for Airplane Design Synthesis. AGARD Lecture, Boeing Document D6-40090, March 15, 1972.

9. Williams, Bill: Advanced Technology Transport Configurations. J. Aircraft, Vol. 10, No. 6, June 1973.

10. Gregory, Thomas J.; Williams, Louis J.; and Wilcox, Darrell E.: The Airbreathing Launch Vehicle for Earth Orbit Shuttle -- Performance and Operation. J. Aircraft, Vol. 8, No. 9, Sept. 1971.

11. Gregory, Thomas J.; Ardema, Mark D.; and Waters, Mark H.: Hypersonic Transport Preliminary Performance Estimates for an All-Body Configuration. AIAA Paper No. 70-1224.

12. Petersen, Richard H.; and Waters, Mark H.: Hypersonic Transports--Economics and Environmental Effects. J. Aircraft, Vol. 10, No. 6, June 1973.

13. Herbst, W.B.; and Krogull, B.: Design for Air Combat. J. Aircraft, Vol. 10, No. 4, April 1973.

14. Stout, E.G.: Study of Aircraft in Intraurban Transportation Systems. Final Report - Summary - Prepared under Contract No. NAS2-5985 by Lockheed-California Company, Burbank, June 1971.

15. Miller, Ralph E., Jr.: Feasibility Study of an Integrated Program for Aerospace - Vehicle Design (IPAD). Prepared under Contract No. NAS1-11441 by The Boeing Commercial Airplane Company, Aug. 30, 1973.

16. Garrocq, C.A.; Hurley, M.J., et al: Feasibility Study of an Integrated Program for Aerospace-Vehicle Design (IPAD) System. Prepared under Contract No. NAS1-11431 by General Dynamics/Convair Aerospace Division, Aug. 30, 1973.

17. Jones, R.T.: Reduction of Wave Drag by Antisymmetric Arrangement of Wings and Bodies. AIAA Journ., Vol. 10, No. 2, Feb. 1972.

18. Vanderplaats, Garret N.: CONMIN - A Fortran Program for Constrained Function Minimization - User's Manual. NASA TM X-62,282, Aug. 1973.

19. Carmichael, Ralph L.; and Gregory, Thomas J.: Computer Graphics in Preliminary Aircraft Design. Presented at the First USA-Japan Computer Conference, Tokyo, Japan, October 3-5, 1973.

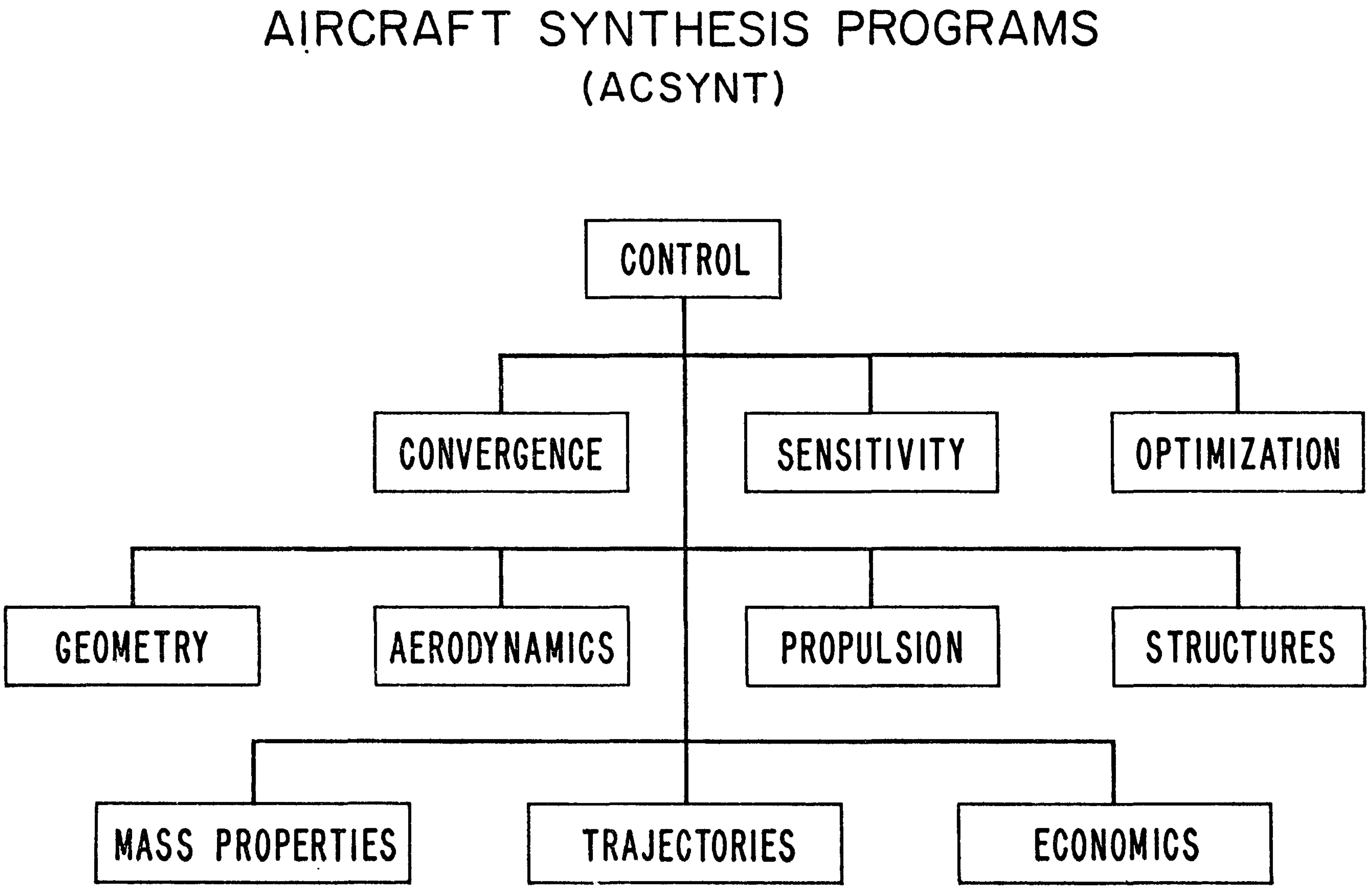


Figure 1.- Aircraft synthesis program disciplines.

DESIGN LEVELS

	CONCEPTUAL	PRELIMINARY	DETAIL	FINAL
OBJECTIVE (OUTPUT)	IDEA DEFINITION ● 3-VIEW SKETCH ● ATTRIBUTES ● PRINCIPLES DEFINED	COMPARISON ● COMPUTED CHARACTERISTICS (3-VIEW DRAWING) ● MANY CONCEPTS ● FEASIBILITY INFORMATION	RESOURCES PLAN ● COMPONENT DEFINITION ● ASSEMBLY DRAWINGS ● PLAN ● SCHEDULE ● CONTRACT	CONSTRUCTION PLANS ● SHOP DRAWINGS ● MATERIALS LIST ● PROOF TESTS
APPROACH	DRAWINGS ● COMPONENT SHAPE ● PLACEMENT ● CONNECTIVITY CALCULATION ● LIMITED ● ISOLATED	RAPID CALCULATIONS ● BALANCED EFFORT ● SENSITIVITIES ● OPTIMIZATION	ACCURATE METHODS ● EXPERIMENTAL EFFORTS ● MOCK UPS ● DETAILED CALCULATIONS	FORMALIZED METHODS (CERTIFICATION) ● TEST PROGRAM ● ESTABLISHED CALCULATION METHODS ● ALL FLIGHT CONDITIONS CHECKED

Figure 2.- Definition of aircraft design levels.

COMPUTERIZED PRELIMINARY DESIGN PROGRAM FEATURES

- MODULAR
- INTEGRATED
- MULTILEVEL
- SENSITIVITIES
- OPTIMIZATION

Figure 3.- Computerized preliminary design program features.

ACSYNT PRELIMINARY DESIGN LEVELS

GEOMETRY

I STANDARD COMPONENT SHAPES

II ARBITRARY COMPONENT SHAPES

AERODYNAMICS

I COMPONENT DRAG FORMULAS

II FINITE ELEMENT PANELING
AREA RULING

PROPULSION

I 1-DIM CYCLE ANALYSIS
INSTALLATION EFFECT
FORMULAS

II TABLE INTERPOLATION
(MANUFACTURERS DATA)

STRUCTURES

I BEAM THEORY

II FINITE ELEMENTS

MASS PROPERTIES

I 25 ELEMENTS
VOLUME AND C.G.

II >100 ELEMENTS
INERTIAS

TRAJECTORIES

I INTEGRATED
FLIGHT SEGMENTS

II OPTIMIZED FLIGHT
SEGMENTS

Figure 4.- ACSYNT preliminary design levels.

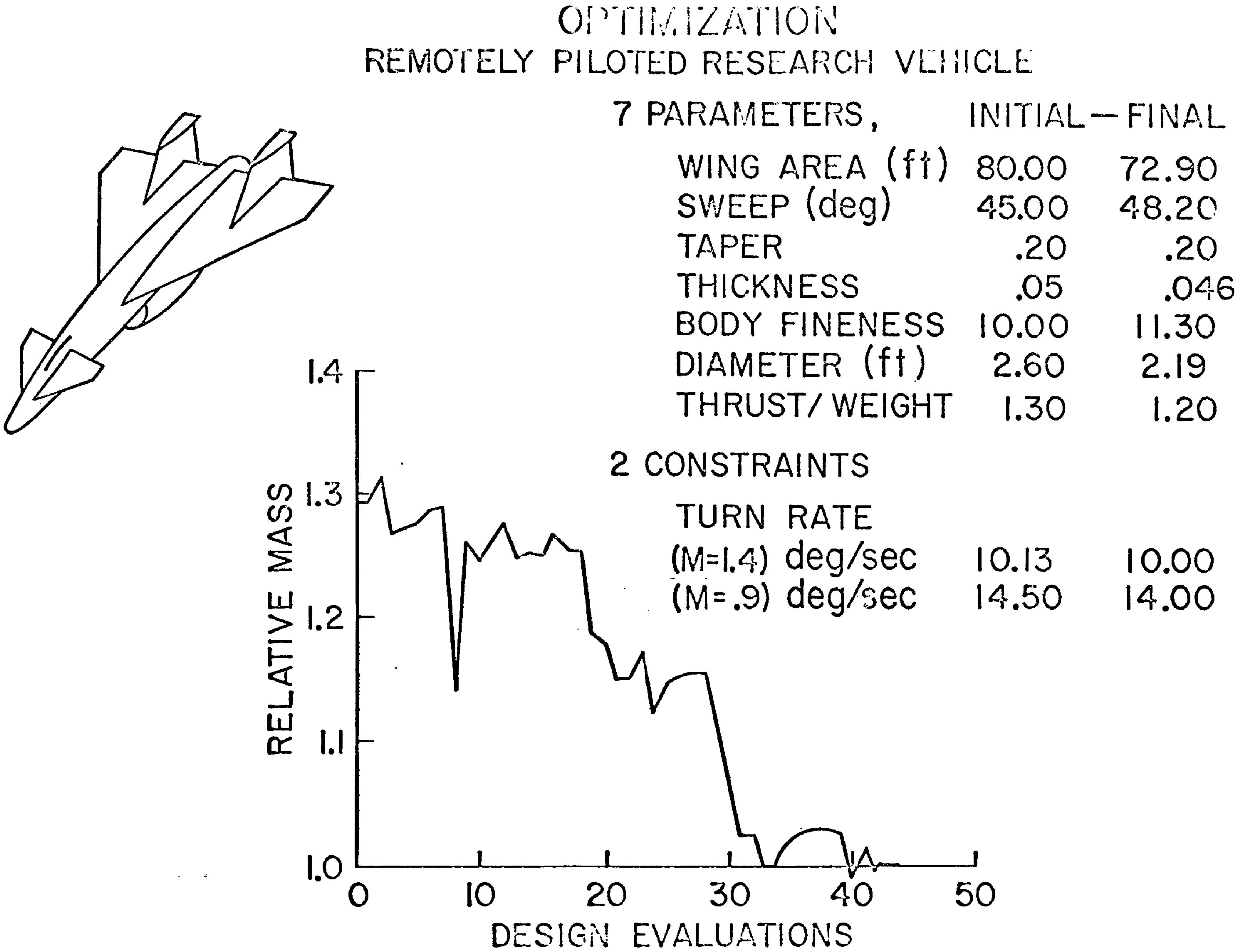
SENSITIVITIES

OBLIQUE WING TRANSPORT

$$\text{WEIGHT SENSITIVITY} = \frac{\Delta\ \text{GROSS WEIGHT/GROSS WEIGHT}}{\Delta\ \text{PARAMETER/PARAMETER}}$$

MISSION PARAMETER	NOMINAL VALUE	WEIGHT SENSITIVITY
PASSENGERS	200	.600
RANGE	3000 n mi	.691
CRUISE MACH NO.	1.15	.986
DESIGN PARAMETERS		
WING LOADING	120 psf	-.263
NOSE FINENESS RATIO	10	.094
WING ASPECT RATIO	12	-.286
WING THICKNESS RATIO	.10	-.0643
BYPASS RATIO	2	.138
EFFICIENCY PARAMETER		
MINIMUM DRAG COEFFICIENT	-	.772
COMPRESSOR EFFICIENCY	-	.713

Figure 5.- Typical sensitivity information.



OPTIMIZATION

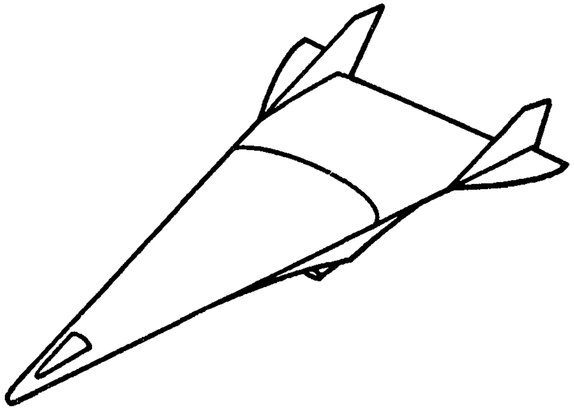
REMOTELY PILOTED RESEARCH VEHICLE

7 PARAMETERS,	INITIAL	FINAL
WING AREA (ft)	80.00	72.90
SWEEP (deg)	45.00	48.20
TAPER	.20	.20
THICKNESS	.05	.046
BODY FINENESS	10.00	11.30
DIAMETER (ft)	2.60	2.19
THRUST/ WEIGHT	1.30	1.20
2 CONSTRAINTS		
TURN RATE		
(M=1.4) deg/sec	10.13	10.00
(M=.9) deg/sec	14.50	14.00

Figure 6.- Typical optimization results for a remotely piloted research vehicle.

VEHICLE OPTIMIZATION

HYPERSONIC TRANSPORT
RANGE = 5500 n. mi.
GROSS WEIGHT = 500 Klbs.



3 SHAPE PARAMETERS	PASSENGER INCREASE
SWEEP	
FOREBODY LENGTH RATIO	130 TO 190
SLENDERNESS	
5 PROPULSION PARAMETERS WITH A SONIC BOOM SAME CONSTRAINT OF 2.5 psf	
TURBOJET SIZE	
RAMJET SIZE	
ROCKET SIZE	73 TO 97
ROCKET IGNITION POINT	
ROCKET SHUTDOWN POINT	

Figure 7.- Optimization results for a hypersonic aircraft.

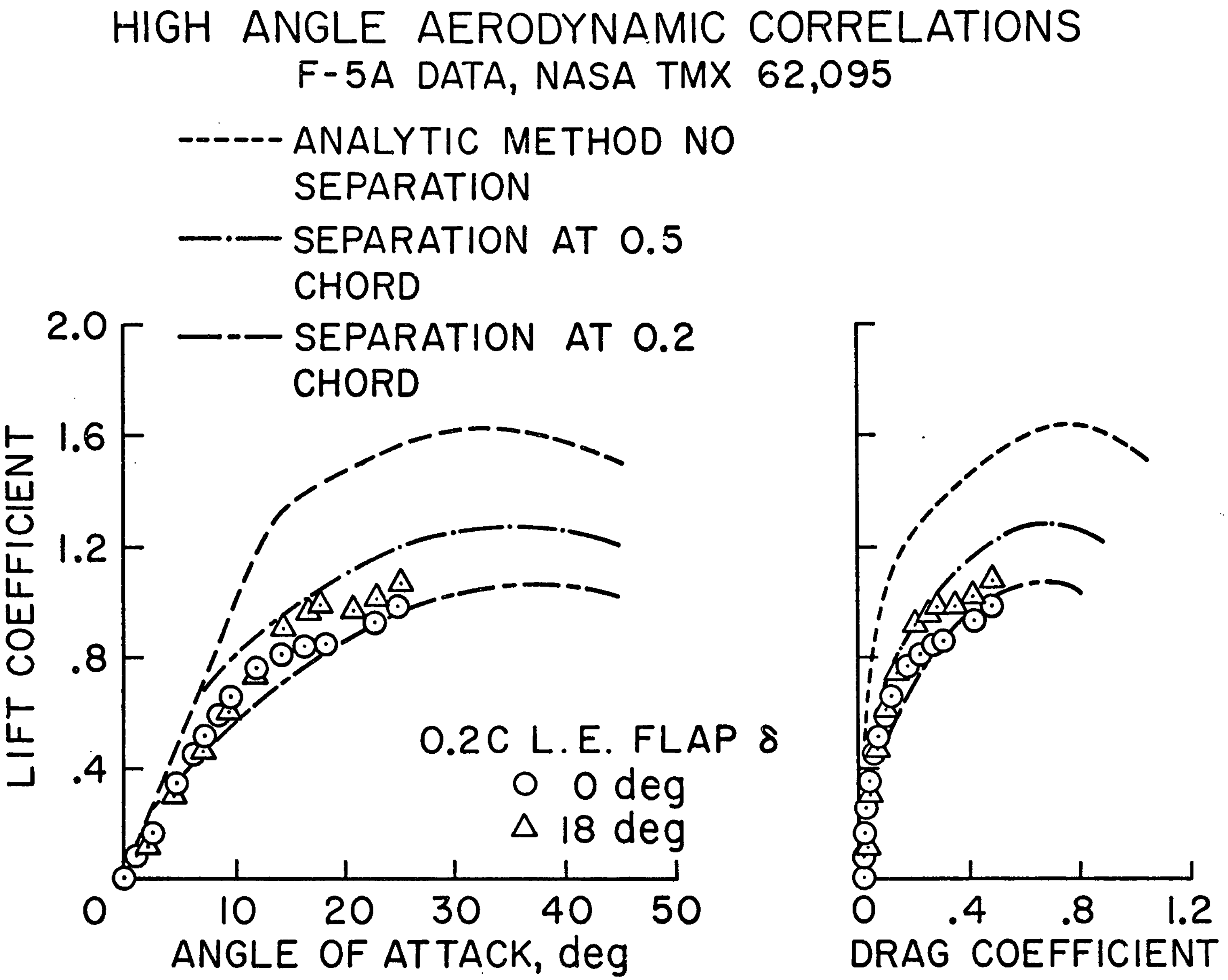


Figure 8.- High angle of attack aerodynamic estimating correlations.

VEHICLE SYNTHESIS CORRELATION

AIRCRAFT — BOEING 727-200
MISSION — PAYLOAD = 163 PASS., RANGE = 2000 N.M., M = 0.82

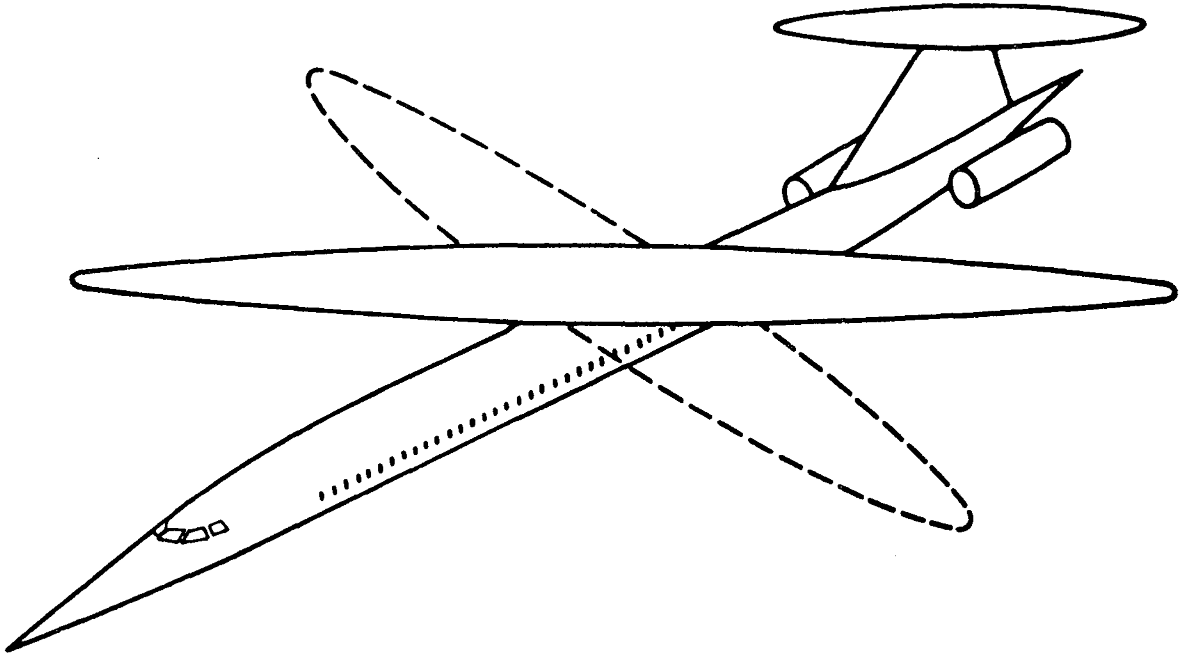
DIMENSIONS

	COMPUTED	ACTUAL	% ERROR
BODY LENGTH, FT	137	131	5
BODY WIDTH, IN.	139	139	0
WING SPAN, FT	110	108	2
HORIZ. TAIL SPAN, FT	40	36	11
NACELLE LENGTH, FT	20.8	17.8	17
NACELLE DIAM, IN.	44	45	-2
WING AREA, SQ. FT	1700	1587	7
H. TAIL AREA	469	376	25
V. TAIL AREA	474	356	33

WEIGHTS

	COMPUTED	ACTUAL	% ERROR
AIRFRAME	54700	53700	2
PROPULSION	11200	12700	-12
FIXED EQUIP.	30000	28300	6
FUEL	46800	42700	10
PAYLOAD	32600	32600	0
GROSS	175000	170000	3

Figure 9.- Overall vehicle synthesis correlation.



OBLIQUE WING TRANSPORT

Figure 10.- Oblique transport configuration.

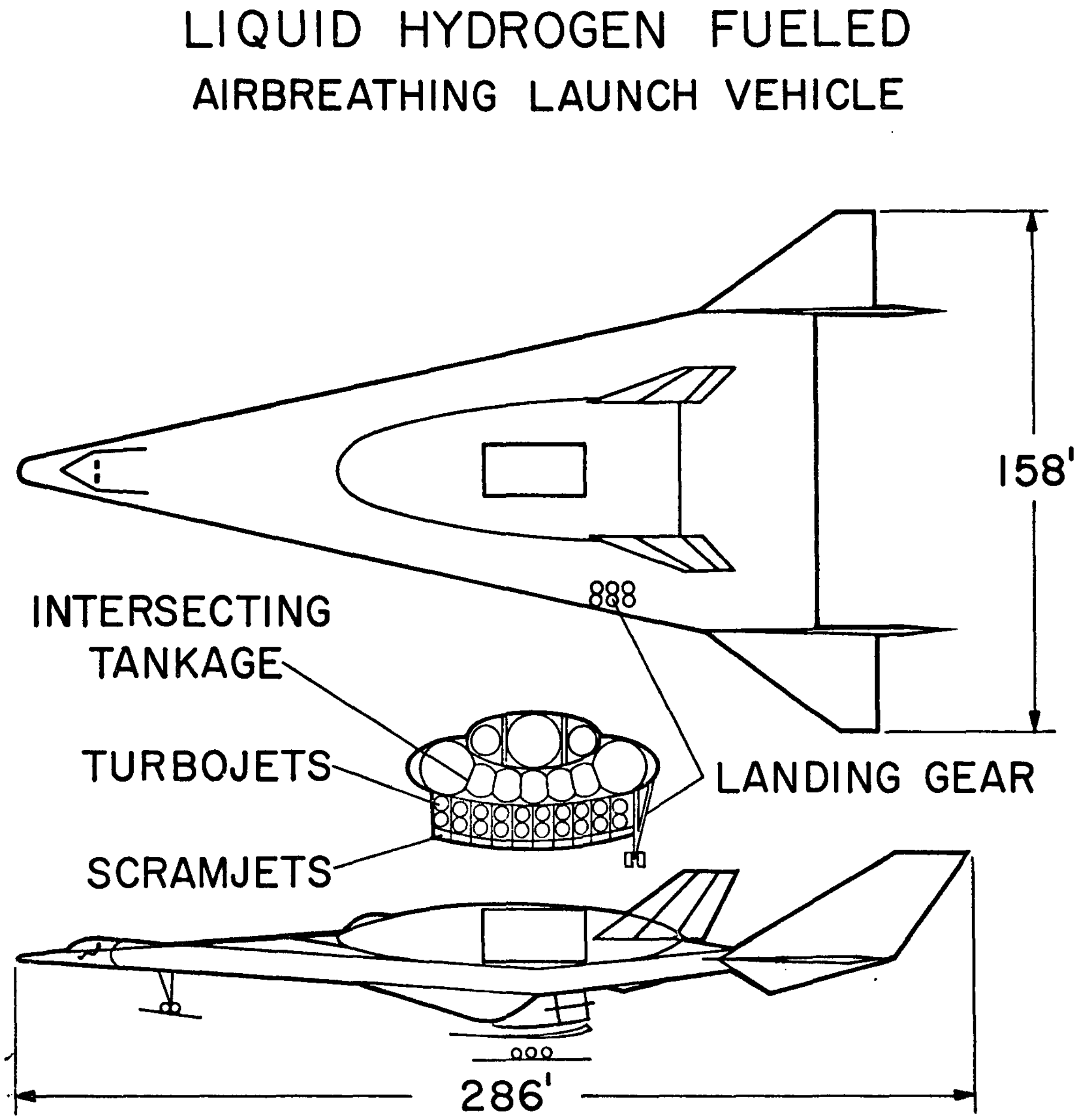


Figure 11.- Liquid hydrogen fueled airbreathing launch vehicle.

Figure 12.- Computer terminal with CRT, keyboard and digitizing tablet.

Figure 13.- Digitized vehicle configuration.

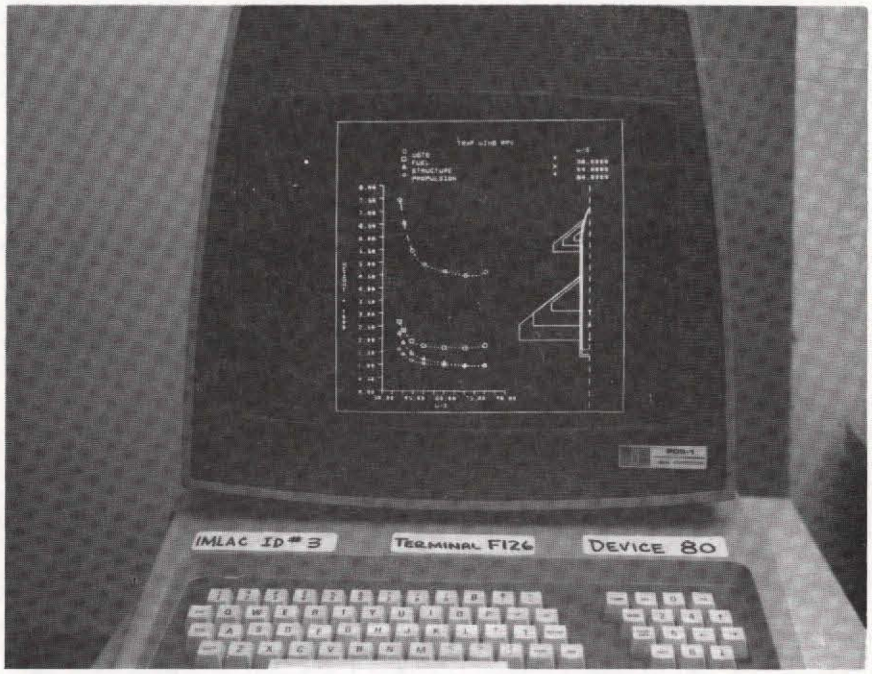


Figure 14.- Display of engineering computations and vehicle geometry.