Computerized Aircraft Synthesis

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A concept and philosophy of computerized aircraft synthesis is discussed, and Computer Program SYNAC (SYNthesis of AirCraft) is examined in some detail by considering examples of both its construction and its application. An aircraft synthesis computer program involves three principal functions: determination of force characteristics, determination of aircraft performance, and configuration control. There are three groups of variables: independent configuration size and shape variables; intermediate weight-, propulsion-, and aerodynamic-force characteristics variables; and dependent performance variables. Program SYNAC is organized in seven major modules: input, configuration control, geometry, weight, propulsion, aerodynamics, and performance. The program yields accuracies comparable with conventional aircraft synthesis techniques. Computer time per problem is currently on the order of 1 min, and ultimate times of $\frac{1}{10}$ of a minute are expected. A typical application of Program SYNAC involves the maximum-range optimization (in terms of wing area, wing thickness ratio, wing aspect ratio, wing taper ratio, and engine size) of a variable wing-sweep configuration for an air-to-ground mission.

Nomenclature

A = area
AR = wing aspect ratio
b = wing span
C_D = drag coefficient
C_{DW} = wave drag coefficient
C_f = friction drag coefficient
C_L = lift coefficient
$C_{L\alpha S}$ = uncorrected slope of lift curve
c = wing chord length
D = drag or diam
e = eccentricity
FF = form factor
FR = fineness ratio
G = aerodynamic parameter = $(2 \cos\Lambda_{c/2})/AR$
g = gravitational acceleration
H = height
h = altitude
IF = interference factor
K_{INL} = inlet weight factor
K_{PIV} = wing pivot weight factor
L = lift or length
M = Mach number
N = ultimate load factor
q = dynamic pressure
R = range or radius
R_N = Reynold's number
S_{TO} = takeoff distance
S_W = wing area
T = thrust
t = time
t/c = wing thickness ratio
V = velocity
W = weight or width
Y = wing station along span
Λ = wing sweep angle
λ = wing taper ratio
μ = friction coefficient

Subscripts

A = inner wing
B = outer wing
b = at wing break
BT = boattail
DES = design value
F or FUS = fuselage
F,S = fuselage-external stores
LE = wing leading edge
NO = nose
0 = initial condition
R = at wing root
S = with wings swept
T = at wing tip
TO = takeoff
W = wetted
W,T = wing-tail

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Introduction

A REQUIREMENT for a new aircraft is established primarily in terms of the performance capabilities that are expected of that aircraft. The basic initial design task is to determine an over-all configuration that will meet the performance requirements and which is, in some sense, the best configuration that will meet them. Definition of *a* configuration that will yield, for example, a given range over a specified mission profile (without regard for the size or the economics of the vehicle) is, in general, a relatively straightforward procedure. However, definition of, for example, *the* minimum gross weight configuration that will do this is a complex undertaking. Indeed, although most resultant configurations are labeled optimum (with the correctness of this assertion usually being somewhat obscured by vagueness regarding the proper definition of optimum and the effects of various constraints), most resultant configurations are, in fact, not the best that could have been devised within the constraints that were assumed.

This general lack of thoroughness in aircraft configuration selection is primarily a consequence of the large number of configuration perturbations that are required to arrive at an optimum and the relatively large effort that is required per perturbation when, in the conventional sense, a perturbation consists of layout by a designer; prediction of aerodynamic, weight, and propulsion characteristics by specialists in these areas; and performance evaluation by a performance engineer. Only recently have the pressures associated with mission complexities, cost effectiveness considerations, and configuration justification requirements obviously dictated a completely computerized approach to the problem, in order to bring to bear the basic computer program advantages of speed, self-contained operation, and consistency. To meet this need for computerized synthesis, the SYNAC series of digital computer programs is currently being developed at the Fort Worth Division of General Dynamics. The concept of computerized synthesis of aircraft is not new, but it is believed that the SYNAC approach—which emphasizes completeness, detail, accuracy, speed, and versatility—is unique.

The SYNAC computer programs are designed to handle conventional takeoff-and-landing subsonic and supersonic aircraft employing airbreathing engines. The first of these programs, SYNAC I, was an experimental version that did not possess full synthesis capabilities. It has been replaced by SYNAC II, which performs the fully automatic synthesis of fighter-bomber-type aircraft. This program will be superseded in turn by SYNAC III, which is currently under development. SYNAC III will extend the range of applicability to other classes of aircraft, and it will have the capability of internally generating various types of optimum configurations subject to a variety of constraints.

It is the intent of this paper to give to the reader an over-all appreciation of 1) the concept of computerized aircraft synthesis and 2) the SYNAC implementation of this concept. The emphasis here is necessarily on over-all because of space limitations. However, it is important that sufficient detail be given to illustrate that the SYNAC approach is firmly based on the conventional process of preliminary design, and is not simply a gross "quickie" approximation of this process. Therefore, both program construction and program application details are presented, but by example, rather than in full.

Table 1 Program SYNAC independent and dependent variables

Independent variables—configuration data	
Wing	Fuselage
Area or wt/wing area	Length
Aspect ratio	Fineness ratio
Inner taper ratio	Nose fineness ratio
Outer taper ratio	Boattail fineness ratio
Inner thickness ratio	Width/height
Outer thickness ratio	
Break chord	Engine
Inner min sweep	Scale factor or aircraft thrust/weight
Outer min sweep	
Inner or outer max sweep	Over-all
Camber (design C_L)	Gross weight
Dependent variables—performance data	
Takeoff	Maneuverability
Ground run	Specific power
Distance to 50-ft alt	Max sustained g
Unstick speed	Time to intercept
50-ft-altitude speed	Other
Accelerate and climb	Landing
Time histories of	Dist. from 50-ft alt
Altitude	Ground run
Mach number	50-ft-altitude speed
Weight	Touchdown speed
Cruise	Over-all
Specified/optimized paths	Range
Variations of	Zone
Altitude	Secondary mission data
Mach number	Other
Weight	

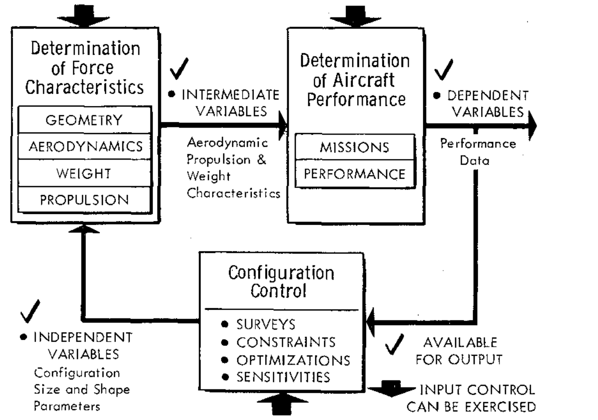


Fig. 1 Over-all arrangement and logic of an aircraft synthesis computer program.

Philosophy and Over-All Logic

One of the most pertinent comments that can be made concerning the subject of computerized aircraft synthesis is that, contrary to some casually obtained impressions, computerized synthesis is not computerized performance computation. The computation of performance constitutes one of the major functions of a synthesis program; however, the kernel of the concept is the definition of aerodynamic, weight, and propulsion forces in response to the arbitrary specification of aircraft configuration variables.

The over-all arrangement and logic of a typical aircraft synthesis digital computer procedure, and of Program SYNAC in particular, is presented in Fig. 1. The primary areas of the program are 1) determination of force characteristics, 2) determination of aircraft performance, and 3) configuration control. Determination of force characteristics is the key program element. The independent variables—configuration size and shape parameters—enter this portion of the program; and the intermediate variables—aerodynamic-, weight-, and propulsion-force characteristics—are generated by it. The performance portion of the program accepts the intermediate-variable force characteristics and delivers dependent-variable performance data.

The configuration control element manipulates the values of the configuration parameters which are being fed to the force characteristics element to achieve various types of configuration changes. In some cases, the control element examines the performance capabilities that are being generated and, through an iterative process, adjusts the configuration variables to achieve desired performance capabilities.

Within the force characteristics element of the program, geometry computations are first performed to generate areas, volumes, and other auxiliary geometric data for use in the force calculations. Aerodynamic-, weight-, and propulsion-force characteristics are then developed. Within the performance element of the program, the initial step is mission definition. This task is followed by cruise flightpath optimizations and performance computations for the various mission phases and for the mission as a whole.

The configuration control element has four basic options: 1) survey (of performance or required weight as a function of configuration variables), 2) constraint (of configuration variables through specification of performance requirements), 3) optimization (of configuration variables to yield maximum performance for fixed weight or minimum weight for fixed performance), and 4) sensitivities (of weight or performance with respect to configuration variables).

Program SYNAC independent variables and dependent variables are listed in Table 1. Geometric independent variables are illustrated in the Geometry discussion. It should be recognized that these variables effectively interchange their

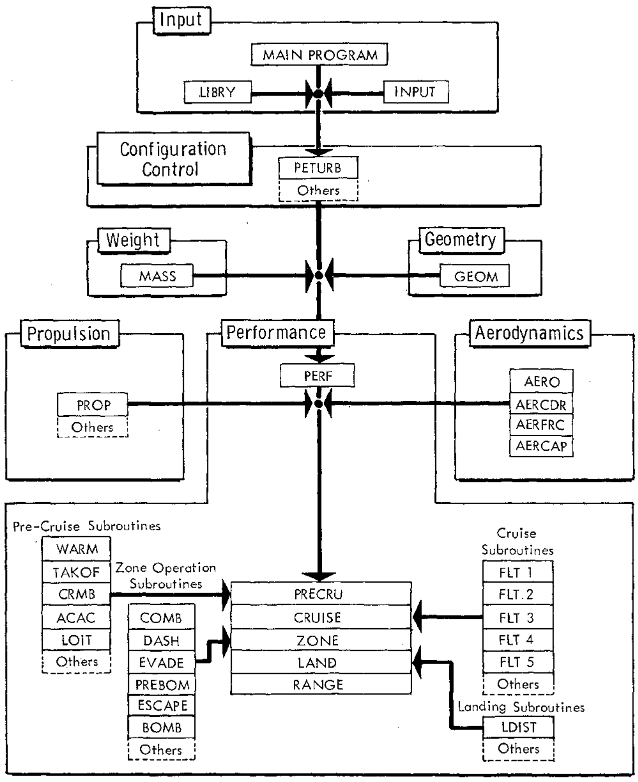


Fig. 2 Basic relationships of Program SYNAC modules and subroutines.

roles when performance is specified and weight is left free. Program inputs consist of data and control information for the three primary program elements. The principal outputs are vehicle-description data and performance data. In addition, force definitions and auxiliary mission/performance data are available if desired.

The fundamental philosophy of the program can be summarized as follows: It is intended to replace completely the usual manual process of aircraft synthesis which is associated with basic configuration selection. The program is structured to operate at sufficient speed to permit extensive configuration studies that are not feasible with the conventional approach, and to do so at an accuracy level that is consistent not only with tradeoff analyses, but with absolute-value requirements for most preliminary design purposes. Operational versatility is designed into the program to accommodate all of the usual types of configuration studies, plus significant additional capabilities.

Program Construction

Program SYNAC is coded in Fortran IV. It is organized in seven major modules: input, configuration control, geometry, weight, propulsion, aerodynamics, and performance. The concept of basically independent modules is employed to facilitate 1) computational and operational improvements and 2) the accommodation of new classes of aircraft and new types of missions through the use of replacement or alternate versions of particular modules. The basic relationships of the modules and their subroutines are presented in Fig. 2.

Prior to considering each of the program modules individually, it is appropriate to comment on some general aspects of that group of modules which constitutes the synthesis element of the program: geometry, weight, propulsion, and aerodynamics. First, it should be noted that stability and control calculations are handled within the geometry module, since stability and control requirements are currently used only for tail surface sizing. The weight and aerodynamic modules have two major synthesis options: 1) completely self-contained determination of forces (thereby eliminating external interactions), and 2) determination of forces by perturbation from an externally generated set of force characteristics for a reference configuration (thereby permitting periodic alignment with externally developed and analyzed point designs). Currently, the propulsion module varies only engine size for a specific reference engine.

The seven program modules are summarized in the following discussion. It should be noted that the equations that are presented in the accompanying figures are examples only, intended to illustrate the types of relations employed and the depth of the analyses, and that they represent but a small (and essentially random) fraction of the equations that are employed.

Input

The input module accepts library and problem information, and sets these data up in proper form for use by the other modules of the program. The weight, propulsion, and aerodynamics libraries store increments, coefficients, exponents, curve fits, etc. which are used in determining the force characteristics. When a reference configuration is utilized as a baseline from which to perturb the weight or aerodynamics characteristics, this configuration and its force characteristics are also stored as library data.

Configuration Control

The configuration control module of SYNAC II contains only a basic perturbation subroutine. The capabilities of this subroutine are 1) variation of configuration variables to define performance as a function of these variables for fixed gross weight, 2) variation of gross weight to yield a desired value of range for fixed configuration variables, and 3) combination of these modes to obtain gross weight as a function of a configuration variable for fixed range.

Constraint, optimization, and sensitivity capabilities will be available in SYNAC III. All of the dependent performance variables (Table 1) and gross weight will be available for purposes of constraint and optimization. This process will result in the corresponding definition of constrained and optimized values of the independent configuration variables (and gross weight, if it is not constrained or optimized). Whereas, of course, only a single performance variable can be optimized at one time, multiple constraints are possible. The present SYNAC II capability of defining the required gross weight for a specified (i.e., constrained) total range is an example of a pure constraint problem. As an example of a constrained optimization problem, gross weight might be minimized for a fixed basic mission profile, subject to an equality constraint on total range and inequality constraints on 1) takeoff distance; and 2) specific power at a specified Mach, altitude, power-setting, g condition. Alternately, total range might be maximized for fixed weight (which can be directly specified), subject to various performance constraints.

Geometry

In Fig. 3, wing and fuselage geometric relationships are illustrated, and example equations are given for the geometry module. This module computes areas, volumes (total fuselage volume, fuselage fuel volume, etc.), angles, chords, and other geometric quantities from the basic independent configuration variables for use in the weight, propulsion, and aerodynamics modules. Straight and cranked wings and fixed- and variable-sweep wings can be treated.

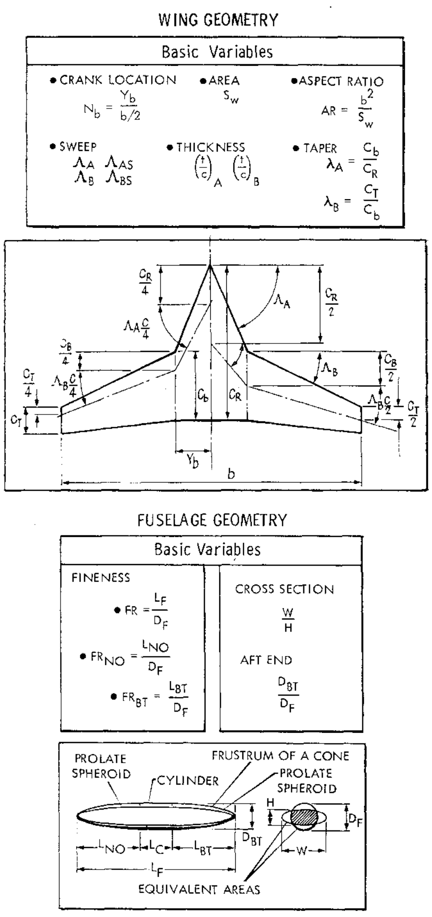
In addition to utilizing a fixed fuselage, there are three options that size the fuselage for required fuel volume (with consideration also given to other volume requirements): 1) L/D (length-to-diameter ratio) fixed, L and D variable; 2) L fixed, D variable; and 3) L variable, D fixed.

Engine inlet/nacelle geometry calculations provide for separate nacelles or engines submerged or semisubmerged in the fuselage. These computations utilize engine diameter and length from the propulsion module.

The horizontal and vertical tail shapes are defined in the same general manner as is the wing shape (but with no provision for crank). The tail surfaces are sized by stability and control requirements. In SYNAC II, simple tail volume specifications are employed; however, in SYNAC III multiple-criteria sizing checks are made for each surface; and, in each case, the largest of the size requirements is used.

Weight

Several example equations from the weight module are presented in Fig. 4. This module computes vehicle weight data using one of two options: 1) general direct buildup and 2) perturbation from a reference configuration by using direct buildup data ratioed to the reference configuration weights. The direct buildup option computes the weights of individual components (wing, fuselage, landing gear, etc.) using relations (documented in detail in Ref. 1) that are primarily empirical. The weight equations are functions of the configuration variables, design values of Mach number and dynamic pressure, and load factor data. They also involve gross weight implicitly, and, therefore, require an iterative solution. Engine weight is supplied by the propulsion module.



EXAMPLE GEOMETRY EQUATIONS

$$A_{W_{NO}} = \pi R^2_F + \frac{\pi L_{NO} R_F \sin^{-1} e_{NO}}{e_{NO}}$$

$$\Lambda_{B\frac{C}{2}} = \tan^{-1}\left[\frac{\left(\frac{b}{2} - Y_B\right)\left(\tan \Lambda_B\right) + \frac{C_T}{2} - \frac{C_B}{2}}{\frac{b}{2} - Y_B}\right]$$

Fig. 3 Geometry module relationships and example equations.

$$W_{WING} = 3.08 \left\{\frac{K_{PIV}\ N \cdot W_{DES}}{t/c}\left[\left\{\tan \Lambda_{LE} - \left(\frac{2(1-\lambda)}{AR(1+\lambda)}\right)\right\}^2 + 1\right] \times 10^{-6}\right\}^{0.593} \left[(1+\lambda)AR\right]^{0.89} (S_W)^{0.741}$$

$$W_{FUS} = 10.43\,(K_{INL})^{1.42}\,(q \times 10^{-2})^{0.283}\,(W_{MAX} \times 10^{-3})^{0.95}\,(FR)^{0.71}$$

$$W_{GEAR} = 62.21\,(W_{MAX} \times 10^{-3})^{.84}$$

Fig. 4 Weight module example equations.

The weight equations currently apply specifically to military fighter-bomber-type aircraft, with different equation constants being used for Air Force and Navy aircraft. However, other values of the equation constants can be used to extend their validity. A comparison of Program SYNAC weights with weights obtained from detailed preliminary-design methods yielded a mean deviation of approximately 3%.

Propulsion

The propulsion module consists basically of a library that defines a reference engine and its characteristics, and a method of scaling these data. It accommodates essentially any type of airbreathing engine. The library contains five groups of data arranged according to power setting: normal rated, military, maximum augmented, unaugmented cruise, and augmented cruise. Propulsion data for the reference engine—thrust/scale factor, fuel flow/scale factor, and airflow/scale factor — are loaded as functions of Mach number and altitude for each power setting. In addition, the library contains a section that defines engine weight and dimensions as functions of scale factor.

At the beginning of a problem, the engine is either sized directly by specification of engine scale factor, or sized indirectly by specification of aircraft T/W at the takeoff condition. If the T/W option is used, engine scale factor is then determined. Using the scale factor, the engine weight, diameter, and length are computed, thereby physically defining a specific engine. For this engine (i.e., scale factor) and for specified values of power setting, Mach number, and altitude, thrust, fuel flow, and airflow are determined. For cruise flight paths, required power settings are determined as part of the cruise path optimization process. Engine weight is used by the weight module, engine dimensions by the geometry module, and engine airflow by the aerodynamics module.

It should be emphasized that, whereas the airframe is truly synthesized (in that both size and shape variables are available for specification and variation), the engine is currently only scaled from a reference engine. However, it is planned that engine synthesis capabilities will be added.

Aerodynamics

The aerodynamics module computes lift and drag coefficients using one of two options (of the same types as the weight module): 1) general direct buildup and 2) perturbation from a reference configuration by using direct buildup data ratioed to the reference configuration data. The direct buildup option is based primarily on the analytical and semi-empirical methods of Ref. 2. The computations involve the configuration variables, Mach number, altitude, and engine airflow. They are arranged by aircraft component (i.e., wing, fuselage, tail, etc.) and by lift and drag source. From the standpoint of source, there are seven major groupings: 1) minimum drag, 2) drag due to lift, 3) trim drag, 4) lift-curve slope, 5) angle of attack at zero lift, 6) incremental lift coefficient, and 7) maximum state-of-the-art L/D. In Fig. 5, several example equations from the aerodynamics module

$$FF_{W,T} = 1 + L\left(\frac{t}{c}\right) + 100\left(\frac{t}{c}\right)^4$$

$$FF_{F,S} = 1 + \frac{60}{(FR)^3} + 0.0025\,FR$$

$$C_f = \frac{0.455}{(\log_{10} R_N)^{2.58}} \qquad \frac{C_f}{C_{fi}}$$

$$C_{L_{\alpha_S}} = \frac{AR\,\pi\,G}{G + \sqrt{G^2\left(1 - \frac{M^2 AR^2}{4}\right)}}$$

$$IF = 0.44 + 0.75 \cos\Lambda_{MAX}\frac{t}{c} - 0.105 \cos^{10.5}\Lambda_{MAX}\frac{t}{c} + 0.41\,M^{3.5}$$

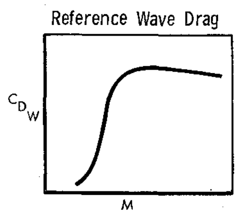


Fig. 5 Aerodynamics module example methods.

are presented and some reference configuration data are illustrated.

Minimum drag has eight contributions: friction, wave, camber, boundary-layer diverter, inlet, base, external-store, and miscellaneous. The friction, wave, and camber drag coefficients are computed internally. The boundary-layer diverter, inlet, base, external-store, and miscellaneous drag coefficients are scaled internally but require library data (as functions of Mach number) that are representative of the general type of configuration that is being considered. Inlet drag computations utilize engine airflow from the propulsion module.

Drag due to lift is computed on the basis of parabolic polars and empirical corrections for nonparabolic variations at high lift coefficients. Trim drag is currently accounted for in a very approximate manner by a problem input multiplier on drag due to lift; however, it is planned that future versions of SYNAC have the option of computing trim drag based on a static moment balance.

Lift-curve slope is internally computed and considers the fuselage as well as the wing. Design C_L is treated as a configuration design variable representative of camber geometry, and it is used to calculate angle of attack at zero lift and incremental lift coefficient for polar displacement.

A gross check is made on the validity of the aerodynamic characteristics that have been defined by comparing a computed value of maximum L/D with an internally stored definition of maximum L/D based on state-of-the-art experience.

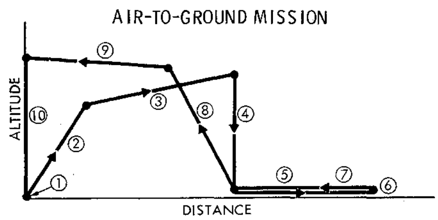
The aerodynamics module accommodates essentially any conventional-takeoff-and-landing subsonic or supersonic aircraft. The accuracy is basically compatible with more detailed preliminary design aerodynamics methods; however, a number of improvements are planned (e.g., in wave drag computation).

Performance

From a manipulative standpoint, the performance module is the most complex section of Program SYNAC. It handles two principal functions: 1) organization and execution of the required computational sequence for a selected mission type and 2) the actual performance computations. A mission type, e.g., the air-to-ground mission shown in Fig. 6, is defined by problem input data either in terms of mission phases (buildup option) or by specification of one of a group of standard library-stored mission types (selection option). The performance computations are conducted, as called for in each mission phase, by appropriate subroutines (Fig. 2), with over-all mission calculations being made at the end of the sequence.

Weight, propulsion, and aerodynamics data are accepted by the performance module from the synthesis modules and used to calculate the dependent-variable performance data that are listed in Table 1. The computational methods vary from 1) simple allowances (e.g., landing reserve fuel), to 2) analytical and semiempirical techniques (e.g., takeoff and landing speeds and distances), to 3) energy-method integrated solutions for specified Mach-altitude paths (for acceleration and climb) and specific-range cruise path integrations. Cruise paths are internally optimized with respect to altitude and/or Mach number. In Fig. 7, some example performance equations are presented and one of several cruise path optimization options is illustrated.

In most cases, Program SYNAC performance computations are as accurate as usual preliminary design performance methods; and, in some cases, they are more accurate.



	Mission Phase	Remarks
1	WARMUP, TAKEOFF, & ACCELERATION TO CLIMB SPEED	FUEL ALLOWANCES FOR SPECIFIED POWER SETTINGS AND TIMES; NO RANGE
2	CLIMB	MILITARY POWER, SPECIFIED MACH NO.; TO CRUISE FLIGHT PATH
3	OUTBOUND CRUISE	MAX RANGE (OPTIMUM ALTITUDE & MACH NO.) SUBSONIC FLIGHT PATH WITH CEILING RESTRICTION
4	DESCENT	TO SEA LEVEL; NO RANGE; NO FUEL
5	OUTBOUND DASH	SEA LEVEL, SPECIFIED MACH NO.
6	(a) COMBAT (b) WEAPON RELEASE	SPECIFIED POWER AND TIME AT DASH CONDITIONS; NO RANGE
7	INBOUND DASH	SAME REMARKS AS 5
8	CLIMB	SAME REMARKS AS 2
9	INBOUND CRUISE	SAME REMARKS AS 3
10	DESCENT & LANDING	SPECIFIED TIME AT MAX ENDURANCE AT SEA LEVEL PLUS PERCENTAGE OF INITIAL FUEL; NO RANGE

Fig. 6 Performance module example mission definition.

Program Application

SYNAC II is currently being employed in support of two preliminary design studies, and its application to a third study has been initiated. Computer times of 1 min/basic synthesis problem (i.e., determination of force characteristics followed by determination of performance) have been typical on the IBM 7090/7040 Direct-Coupled System; however, it is expected that SYNAC III logic and coding improvements combined with the recent changeover to the IBM 360 System (Model 65/40 ASP) will decrease computer times by a factor of 10.

$$S_{TO} = K_1 V_{TO}^2 \ln\left(\frac{1}{1-K_2}\right)$$

WHERE: $V_{TO} = 29.0\sqrt{\frac{W}{SC_{L_{TO}}}}$ $\quad K_1 = \frac{C_{L_{TO}}}{2g(C_D - \mu C_L)}$ $\quad K_2 = \frac{C_D - \mu C_L}{C_{L_{TO}}\left(\frac{T}{W} - \mu\right)}$

$$t = t_o + \int_{h_o}^{h} \frac{dh}{\left[\frac{\left(\frac{T-D}{W}\right)V}{1 + \frac{V}{g}\frac{dV}{dh}}\right]}$$

FLIGHT PATH OPTIMIZATION

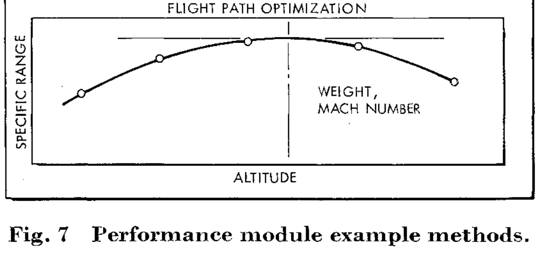


Fig. 7 Performance module example methods.

Program SYNAC is designed to handle a large number of types of aircraft synthesis and performance analysis problems. In the following discussion, three fundamental types of applications are described, and two of these are illustrated by SYNAC II example results. Each of the two examples is based on a set of different mission requirements to be accomplished by a variable-wing-sweep aircraft. In order to present the examples as unclassified, some of the data are normalized to reference values. It should be noted that the results that are presented are selected examples and are representative of only a small portion of the capabilities of Program SYNAC.

Basic Synthesis Problem

The basic mode of operation of Program SYNAC utilizes a specified set of independent configuration variables (Table 1) and specified maximum gross weight to 1) synthesize an aircraft and determine its force characteristics (weight, propulsion, and aerodynamic), and 2) generate its performance (Table 1). If the force characteristics have been defined external to the program, they may be loaded as reference values (as previously discussed), and SYNAC becomes a performance computation procedure.

Aircraft Sizing

As with the basic synthesis mode, the SYNAC sizing mode utilizes a specified set of configuration variables. However, a desired performance capability, usually range, is specified in place of maximum gross weight; and the gross weight that is required to yield the desired performance is iteratively determined by the program. The basic synthesis mode forms an integral part of the sizing mode, and several synthesis problems usually occur in the process of arriving at a solution to a sizing problem.

In Fig. 8, some example results are presented for a sizing problem based on a ferry mission. Configuration variables and values of desired range were problem input data. For each desired range, the program sized the aircraft by varying fuel weight. The fuel variations automatically resulted in the recomputation of the corresponding required dry weight.

Configuration Survey and Optimization

Program SYNAC is primarily designed for use in configuration survey and optimization studies. There are two major options for such studies: 1) fixed gross weight, and 2) fixed performance, usually range. If aircraft gross weight is fixed, the configuration variables are changed, and range effects are determined. If range is fixed, the configuration variables are changed, and gross weight effects are determined. The fixed-weight option utilizes the sizing mode, which, in turn, contains the basic synthesis mode.

In Figs. 9 and 10, some example results are presented for a group of configuration survey and optimization problems based on an air-to-ground mission. A single value of gross weight and a systematic variation of values for configuration variables were problem input data. Configuration variable effects on range for a fixed gross weight were thereby generated for five selected parameters: wing area, wing aspect ratio, wing thickness ratio, wing taper ratio, and engine scale (i.e., engine size relative to a reference engine).

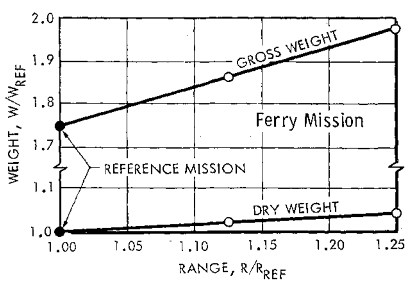


Fig. 8 Aircraft sizing example.

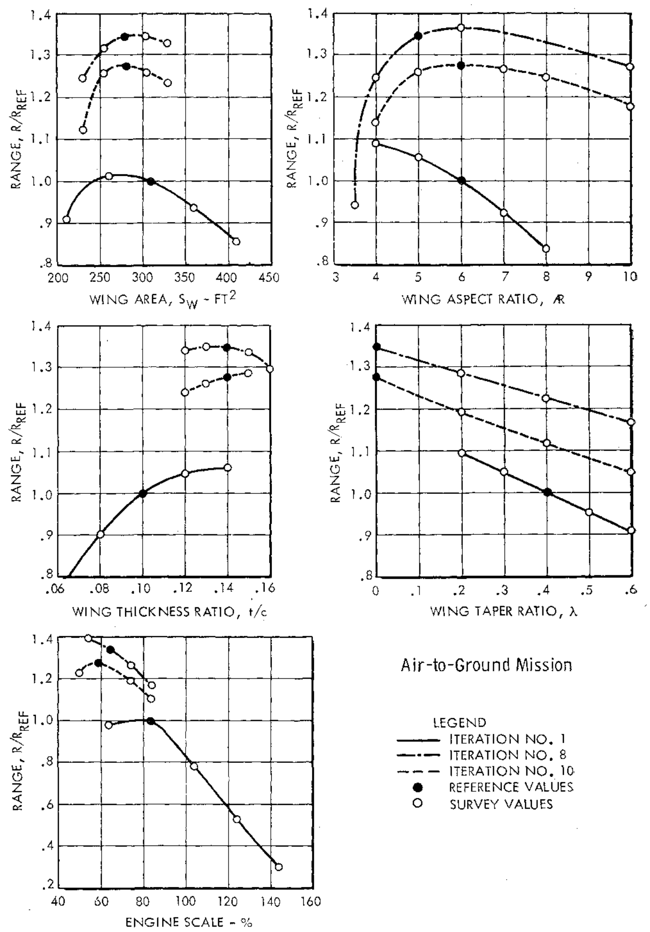


Fig. 9 Configuration survey example.

The curves of Fig. 9 illustrate typical variations of range with each of the five configuration variables investigated. Each of the reference points (solid circles) represents a com-

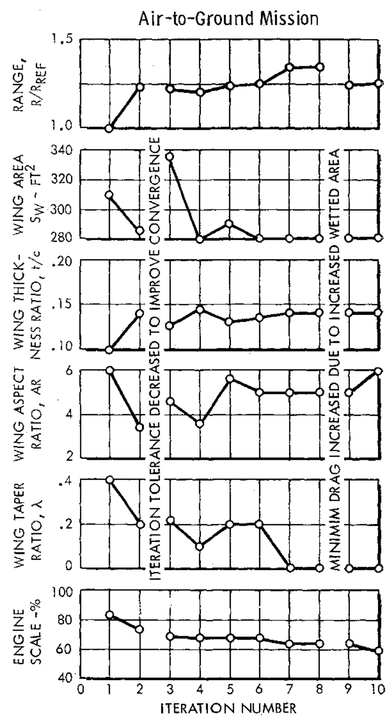


Fig. 10 Configuration optimization example.

plete initial set of configuration variable values from which a survey is made of one variable at a time.

Although SYNAC III will have internal capabilities for configuration optimization (i.e., in this case, variation of these five configuration variables so as to maximize range for a fixed gross weight), this task is currently being handled external to SYNAC II. In Fig. 10, an example iteration history is presented for this method of configuration optimization. The three sets of surveys shown in Fig. 9 were selected to illustrate the convergence of the process. After the second run, a tolerance change was made on an internal iterative calculation to improve accuracy. The eighth configuration is near optimum, with only engine size and aspect ratio not occurring exactly at the maximum range points. Two more runs here would probably have produced an optimum, but, at this point, it was decided that the computed wetted area did not accurately reflect the semisubmerged nacelle arrangement being used. Therefore, the wetted area was subsequently increased by 16% with a multiplicative constant, thereby causing a drag increase and a range decrease. After two more runs, only the wing thickness ratio is off of the peak. A few more iterations would yield complete convergence to the maximum-range configuration.

SYNAC III will handle this optimization process internally, and will use a more sophisticated technique. All of the configuration variables will be available for optimization or constraint.

Conclusion

Computerized aircraft synthesis, as implemented in the current operational version of Program SYNAC (SYNAC II), has proved to be an extremely valuable tool in support of aircraft preliminary design studies. This program has been used to conduct extensive configuration surveys and optimizations that, in general, would not have been feasible without the program. SYNAC III, which is currently being developed, will be considerably more efficient and versatile than SYNAC II; and following SYNAC III, further improvements and extensions are planned.

References

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