High-Speed Research Program Systems Analysis Activities at Ames Research Center

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The Systems Analysis Branch has been working to support the High-Speed Research Program for nearly one year now. This talk will present both the status of methodology development activities and the results of studies either completed or underway.

The initial discussion will involve the conceptual design synthesis program used for HSCT studies, ACSYNT, and enhancements that have been made specifically for HSRP.

The remainder of the talk will present some results for one study that has been completed and two that are underway. These are the advanced controls integration study, the fuel cost impact study, and the oblique wing configuration evaluation that is part of a larger innovative concepts investigation.

The talk will conclude with summary comments and observations.

Outline

- Design Synthesis Tool and Recent Enhancements
- Advanced Controls Integration Study Results
- Early Fuel Cost Impact Study Results
- Early Oblique Wing Configuration Study Results
- Summary

ACSYNT (AirCraft SYNThesis) is NASA Ames' high performance aircraft conceptual/preliminary design synthesis computer program. It was originally developed at Ames in the early 1970's and has been in continuous use and modification ever since. It is characterized by a parametric description of a configuration, automatic design closure, and an integral optimization code. A key enhancement has been the Virginia Tech-developed geometric modeler that uses parametric variables to construct a NURBS (NonUniform Rational B-Spline) three-dimensional model for higher-order analysis and graphics. This module is shown as the interactive 3-D CAD element. While other methods are used for HSR studies within the branch, ACSYNT is the dominant tool.

The ASYNT Institute has been created as a joint enterprise between NASA, industry, and academia to actively develop and support the code among member organizations. Member organizations include many those currently involved in the HSRP, such as Boeing Comercial Airplanes, McDonnell-Douglas, General Electric Aircraft Engines, NASA Langley and NASA Lewis.

The new or substantially-enhanced modules necessary for HSR studies are highlighted in the figure.

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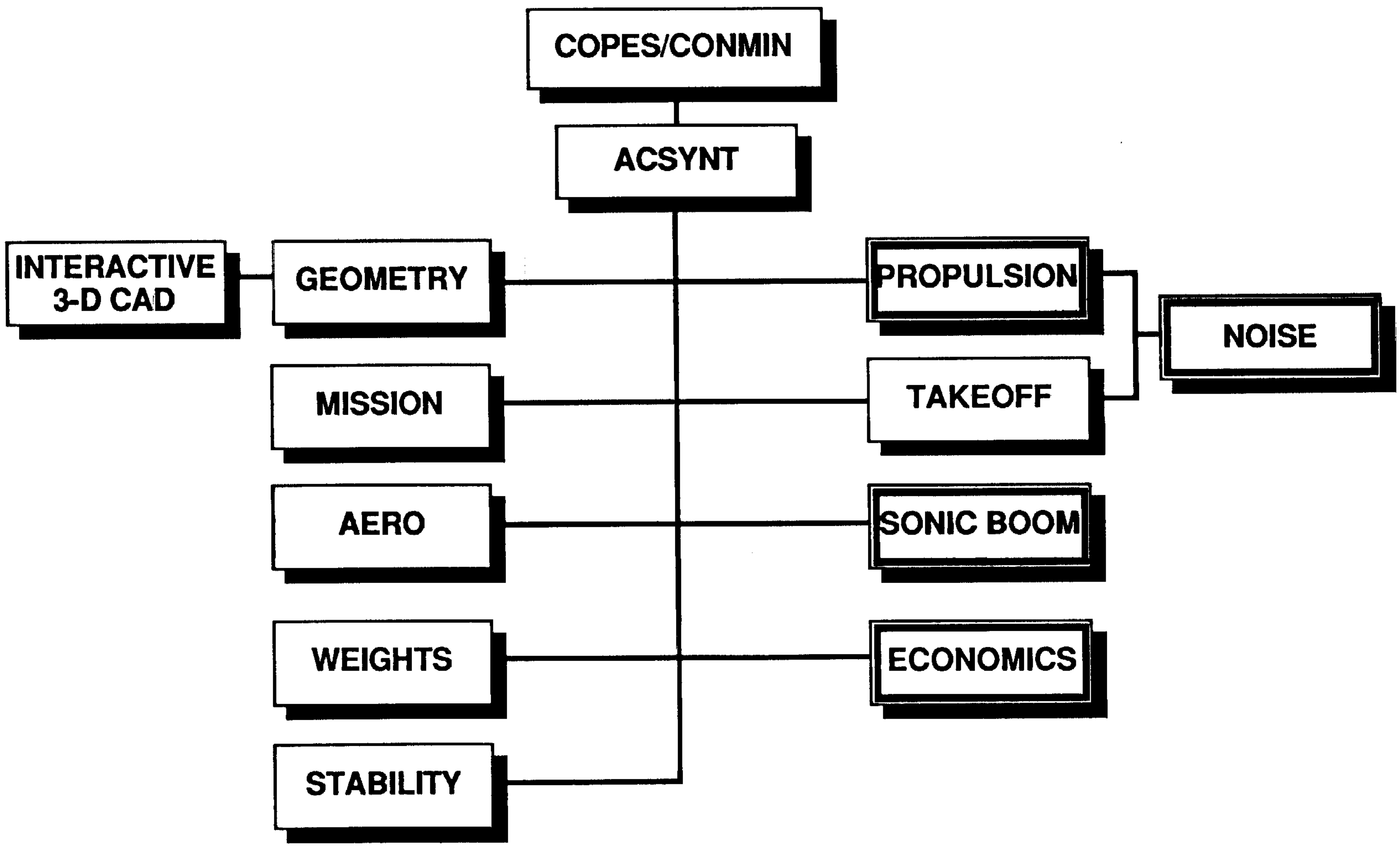
ACSYNT Structure



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This figure shows the ACSYNT workstation display. It displays both wireframe as well as solid representations of the subject design.

The configuration has been defined solely using ACSYNT's parametric variables without any CAD manipulation of the geometry. A future development will allow the user to interactively modify the geometry and have it put back into parametric form for subsequent ACSYNT analysis and resizing.

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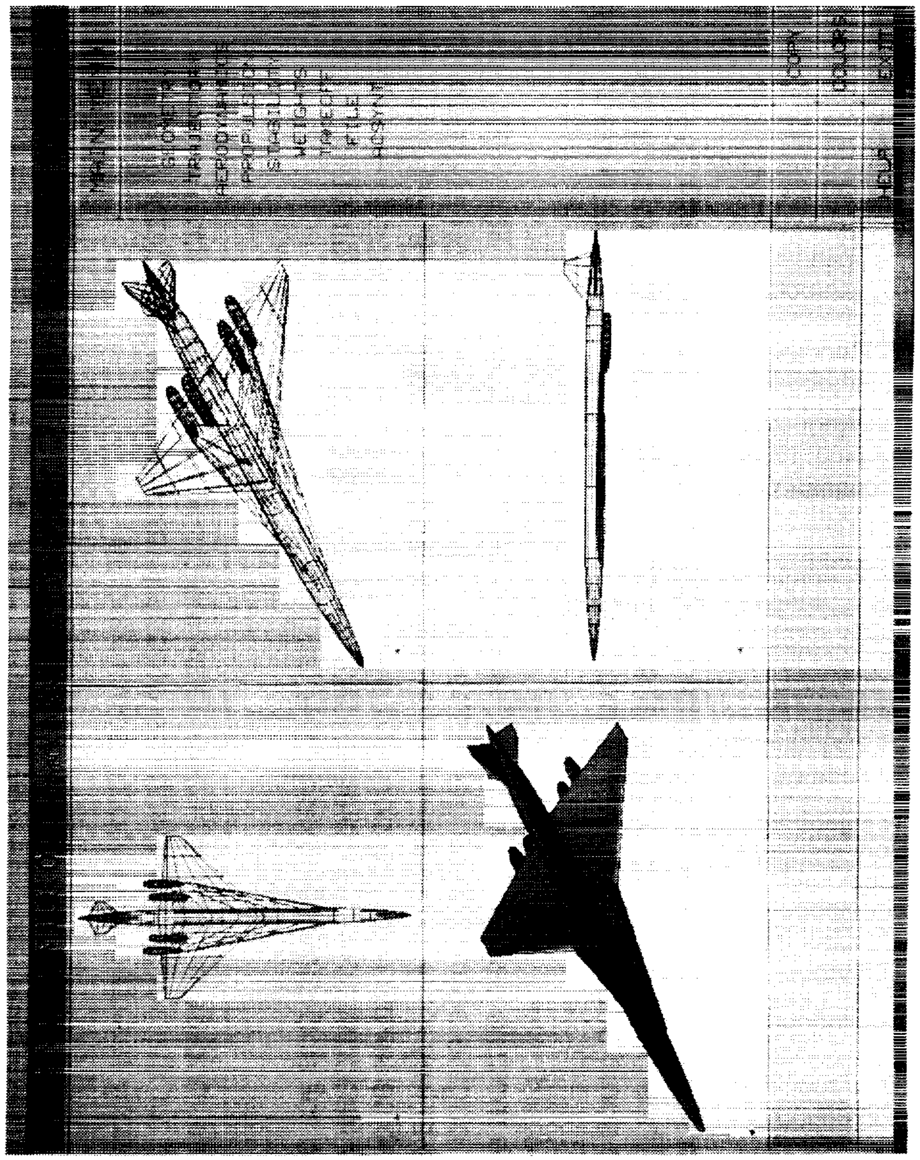

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There have been several major enhancements to ACSYNT in response to HSR goals and constraints. These are the incorporation of sonic boom, economic, and noise analysis modules The sonic boom and economic modules will be discussed in subsequent charts.

The takeoff noise module used with ACSYNT is the NASA Lewis program FOOTPR. It makes use of engine source noise generation with local noise attenuation to determine EPNdB levels at key ground locations. Within ACSYNT, it is used to evaluate FAA flyover and sideline noise levels during sizing and optimization. ACSYNT's takeoff module, a two-degree of freedom time-step integration digital simulation, is used to determine the takeoff ground roll and climbout characteristics.

The aerodynamics module has been improved by integrating the aerodynamic analysis methods used for the sonic boom with the aerodynamics module parametric methods, as opposed to strictly residing in the sonic boom module.

The propulsion module has been improved in two ways. First, methods have been developed to expand an engine database based on sparse data. Also, the cycle analysis option is being significantly improved to permit accurate estimates of propulsion system performance based on engine cycle data.

ACSYNT Enhancements for the HSR Program

- Sonic Boom Module Development and Integration
- Economic Module Integration
- Takeoff Noise Module Integration
- Advanced Aerodynamic Methods Integration
- Propulsion Cycle Analysis Enhancement

A sonic boom module was added to ACSYNT to permit the evaluation of sonic boom characteristics during the design synthesis process. The analytical method was constrained by the need for rapid execution and compatibility with the ACSYNT geometric model

The analysis makes use of three existing computer programs. The Harris wave drag routine is used to compute the equivalent body of revolution due to volume. A supersonic wing analysis (Carlson and Miller) computes the chordwise lift distribution, and hence the equivalent area due to lift. With the complete equivalent body of revolution known, the sonic boom propagation code of Hayes, Haefel, and Kulrud is used to extrapolate the signal and locate any shocks. This integrated analysis code allows the user to easily input an arbitrary aircraft configuration and calculate lift, drag, moment, and sonic boom characteristics. The user input is either a simple parametric description or a CAD-generated description of the aircraft. The geometric modeller makes it possible to use this analysis with a parametric definition of the vehicle.

The results from this module can be used in several ways. During configuration optimization, the sonic boom overpressure can be used as a constraint to make certain some maximum value is not exceeded. Also, the sonic boom characteristics can be used as the objective of the optimization in an effort to minimize one of the key parameters (overpressure, etc.). Of course, these results can merely be passed to the user for information and not used in the course of an optimization.

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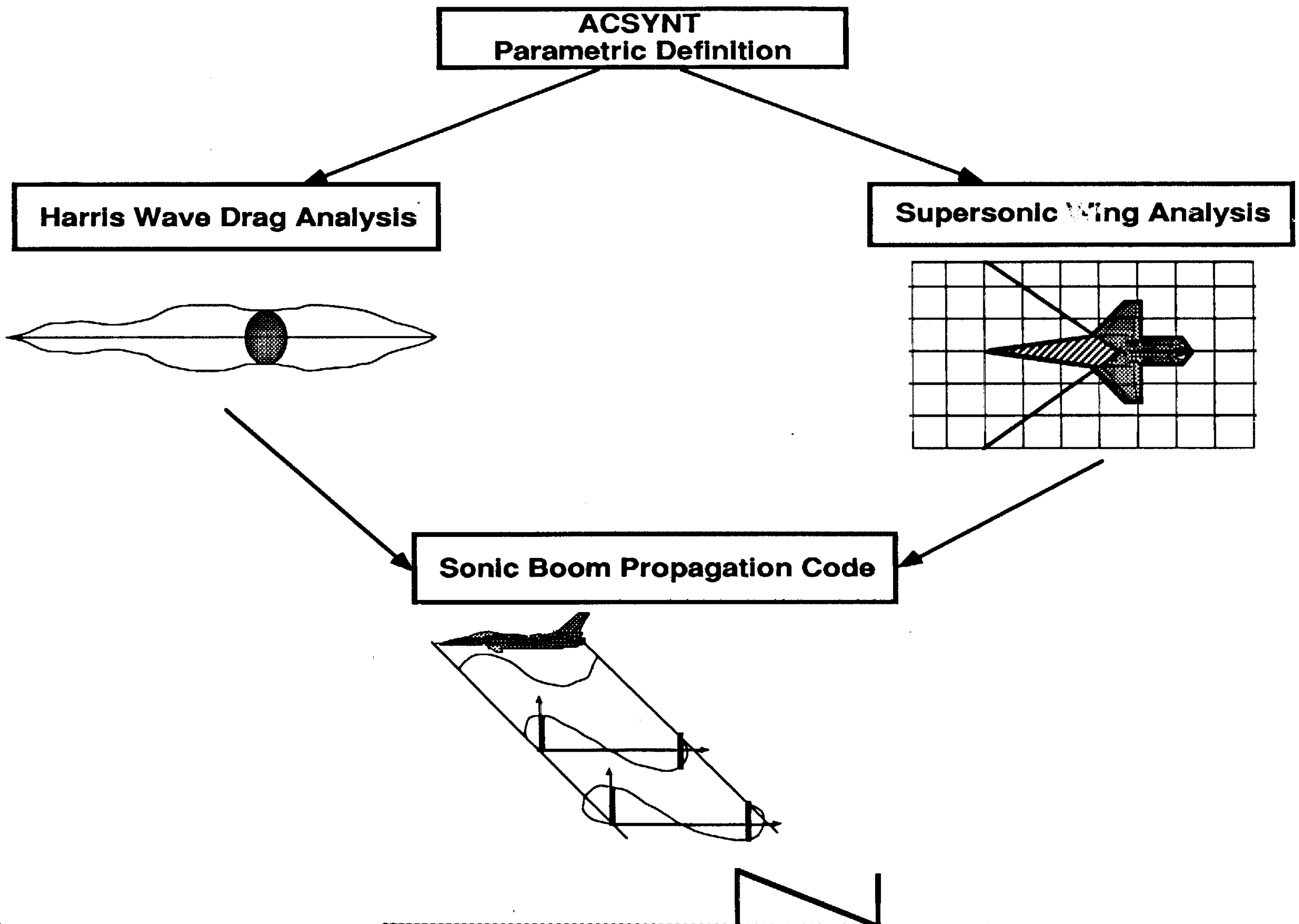
ACSYNT Sonic Boom Module



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The transport cost module for ACSYNT consists of four major components as shown on the facing chart. Two components, Aircraft Manufacturing Costs and Manufacturer Return on Investment (ROI), assess economic parameters critical to production viability. The other two components, Airline Operating Cost and Airline ROI, determine the potential viability for a typical airline operation.

The Aircraft Manufacturing Costs consist of research, development, test and engineering (RDT & E), and production manufacturing and sustaining costs for a range of production quantities to determine unit cost to build.

Manufacturer ROI considers the cash inflows and outflows over a specified development and production period to assess the cost to build and pricing required to achieve a reasonable return on investment.

Airline Operating Costs consist of the direct costs associated with operating the aircraft and indirect costs related to servicing the aircraft and passengers for various stage lengths.

Airline ROI analyzes the operator's cash flow over a specified operating period and assess the revenue requirements in relationship to aircraft price to achieve an acceptable return on investment.

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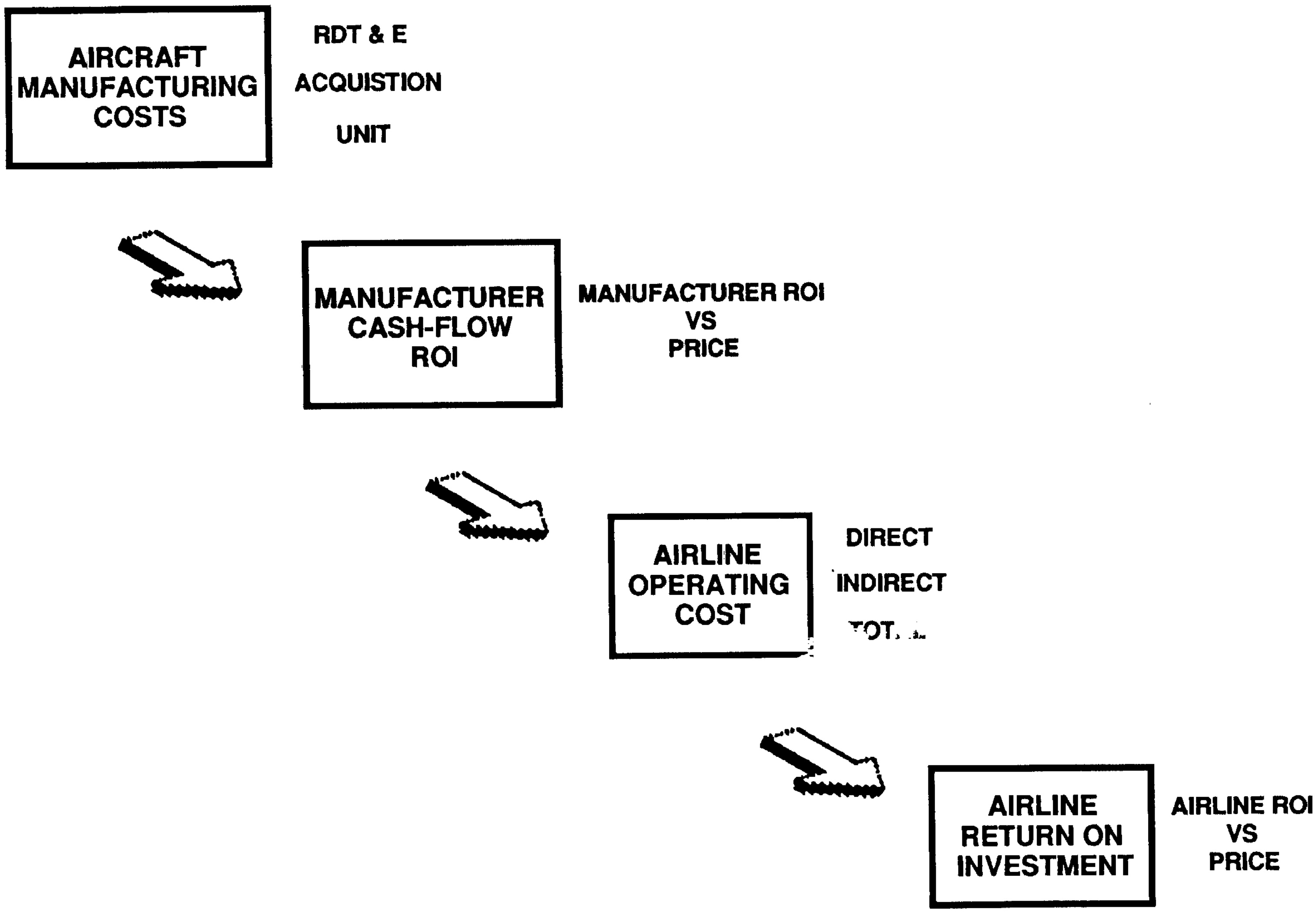
ACSYNT Transport Cost Module Flow



Systems Analysis Branch

The facing chart depicts the flow of data and input parameters for the ACSYNT transport cost module. There are two basic paths that are of interest. One is to estimate the manufacturers unit cost and typical airline operating costs. The second, more detailed, path is to assess the potential rate of return on investment (ROI) to both the manufacturer and airline operator over a specified period of time as affected by aircraft price, airline revenue, and aircraft production quantity.

ACSYNT weight, propulsion, and performance modules are utilized to determine the aircraft component weights, engine size, and mission performance parameters, such as block time and fuel, that are passed to the modules that determine aircraft manufacturing and airline operating costs. Additional parameters, such as labor rates, learning curves, production quantity, fuel costs, and operational factors are input separately.

If ROI calculations are desired, additional production, payment, and depreciation schedules over a specified time period are required. Manufacturer ROI is determined as a function of aircraft price for various production quantities and Airline ROI is determined as a function of price for various revenue levels. The required production quantity and revenue level can then be determined to achieve viable ROI's for both the manufacturer and operator.

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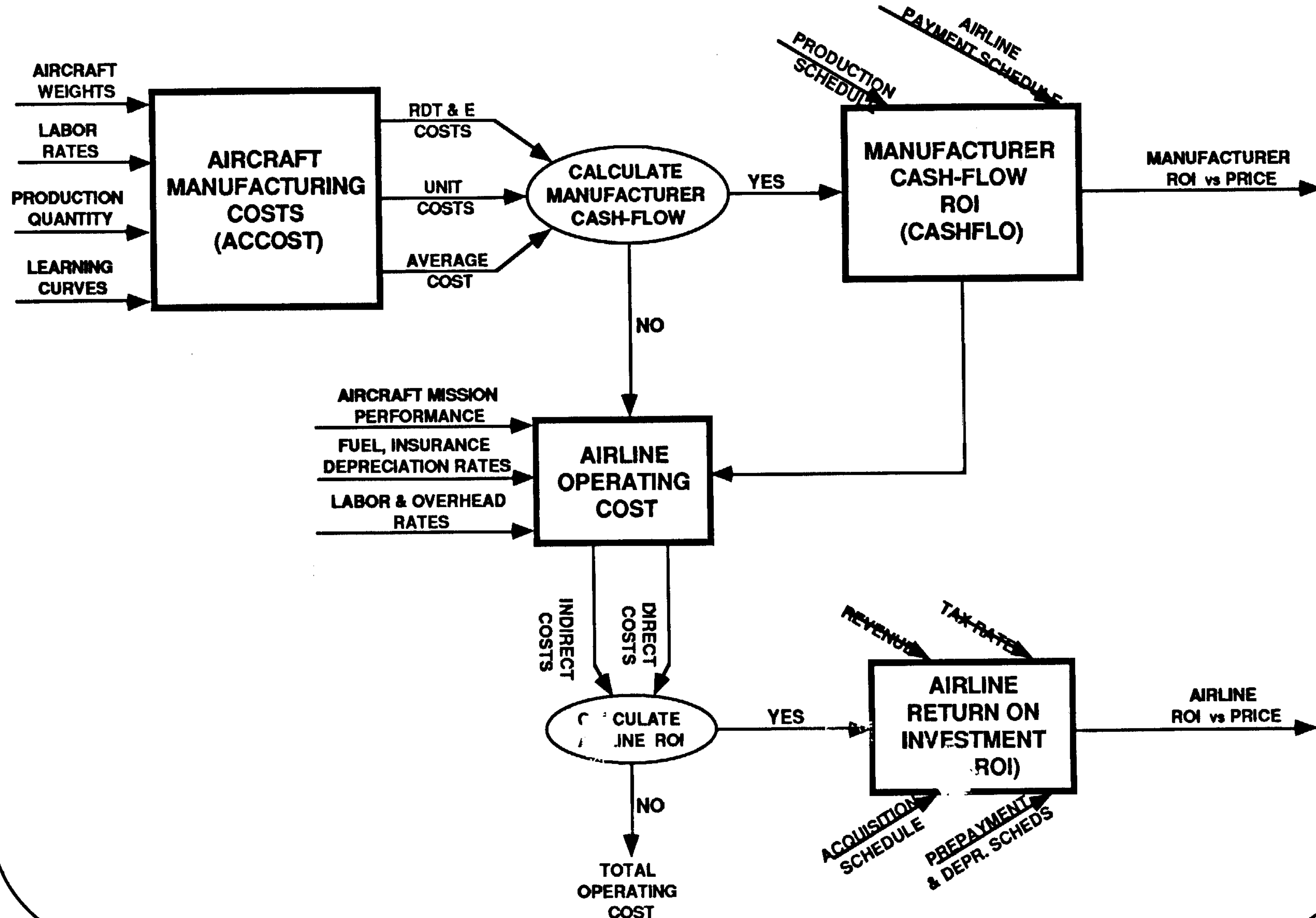
ACSYNT Transport Cost Module Details



Systems Analysis Branch

This figure shows the result of a correlation between measured sonic boom overpressure at the ground for the Concorde and predicted levels using ACSYNT. In general, the agreement is good except for a small overprediction in magnitude and a stretching of the time scale. The error is possibly due to inaccuracy in the geometric model of the Concorde due to a lack of detailed configuration data and efforts are underway to complete the validation.

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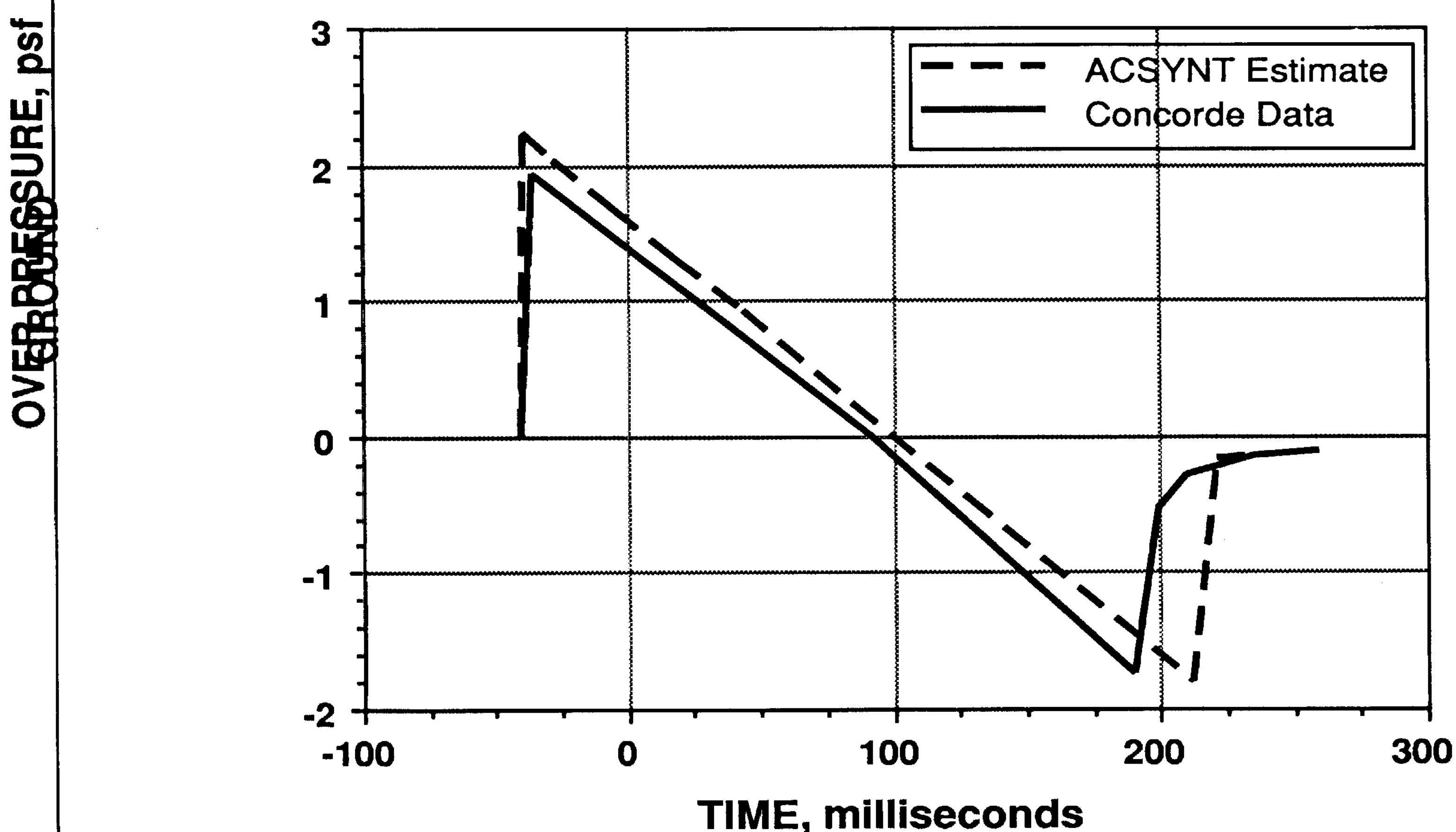
Sonic Boom Estimate Results



Systems Analysis Branch

This figure shows a typical use of the sonic boom analysis in parametric sensitivity studies. Specifically, it shows how takeoff gross weight and sonic boom overpressure vary with fuel reserve requirements. Increasing reserve requirements increases the fuel weight and through the growth factor, the aircraft gross weight. The overpressure varies with vehicle size and weight.

The significance of this figure is the speed in which parametric tradeoffs can be performed. The five datapoints were achieved with a single run of ACSYNT lasting only several minutes on a Silicon Graphics Iris workstation.

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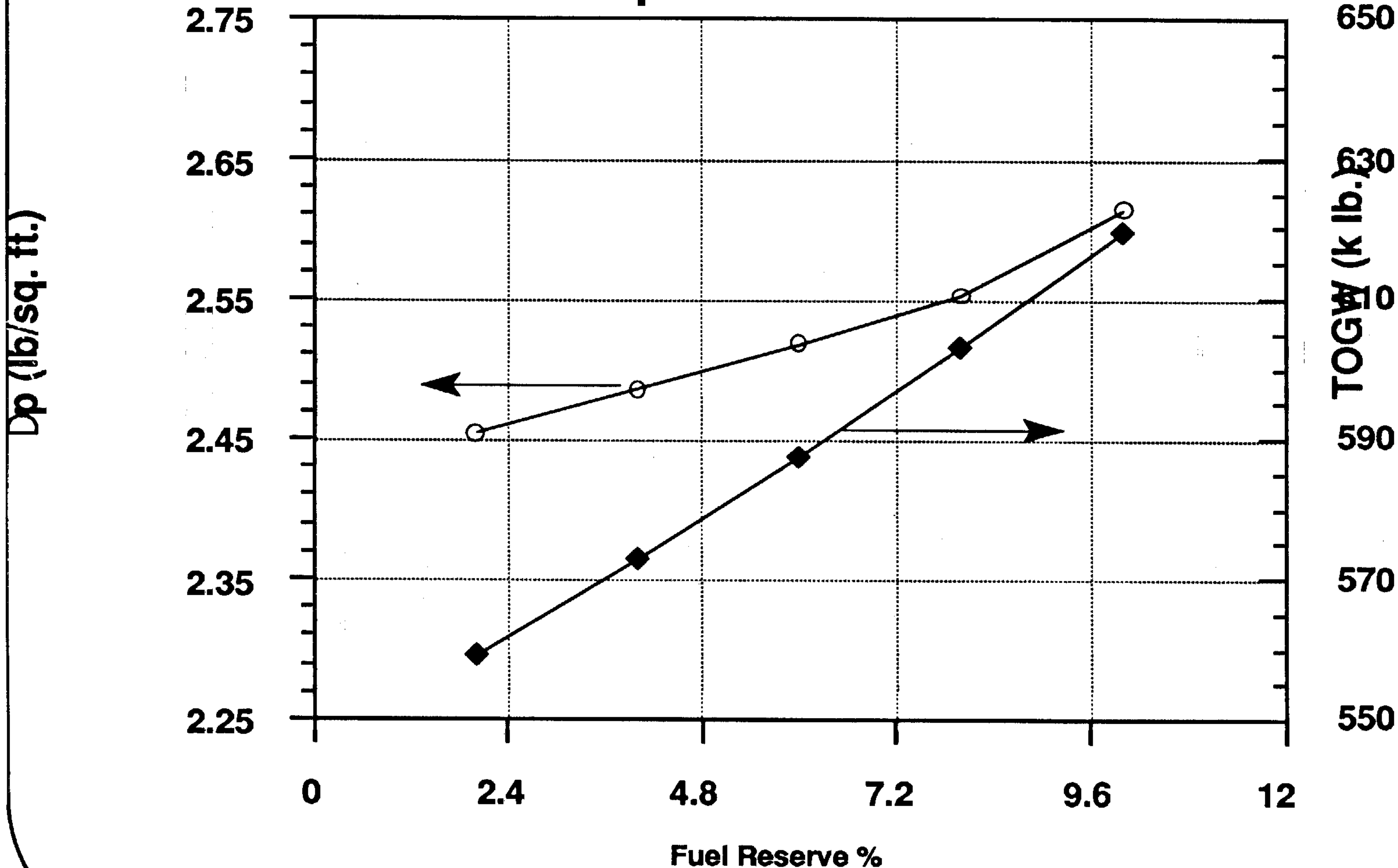
Sensitivity of Boom and Gross Weight to Required Fuel Reserve



Systems Analysis Branch

This figure presents a summary of the results of a study of integrated flight-propulsion control concepts for HSCT aircraft. In this study, advanced control concepts are identified and their impact on the propulsion and/or airframe estimated. The impact on the integrated vehicle of these effects, individually and together, was evaluated using ACSYNT. The baseline design used 1995 technology engines, carried 250 passengers, and had a range of 5,000 nm. at Mach 2.4 with normal reserves.

The results show the benefits of the following concepts:

- integrated engine/flight controls, producing reductions in engine and nozzle weight.
- integrated inlet/engine/flight controls, producing lower inlet drag (expressed as a percent decrease in aircraft drag), and higher inlet recovery and maximum thrust.
- performance seeking control, resulting in improvement in cruise SFC.
- automatic control of engines following engine loss at takeoff rotation, leading to reduced vertical tail size.
- emergency minimum thrust mode, enabling an inlet weight reduction.
- integrated control architecture, leading to a 20% flight control system weight reduction.

As shown, the combined impact on the vehicle is more than 5%. Details of this study are available in SAE conference paper 901928 or NASA TM 101728 by Burcham, Gilyard, and Gelhausen.

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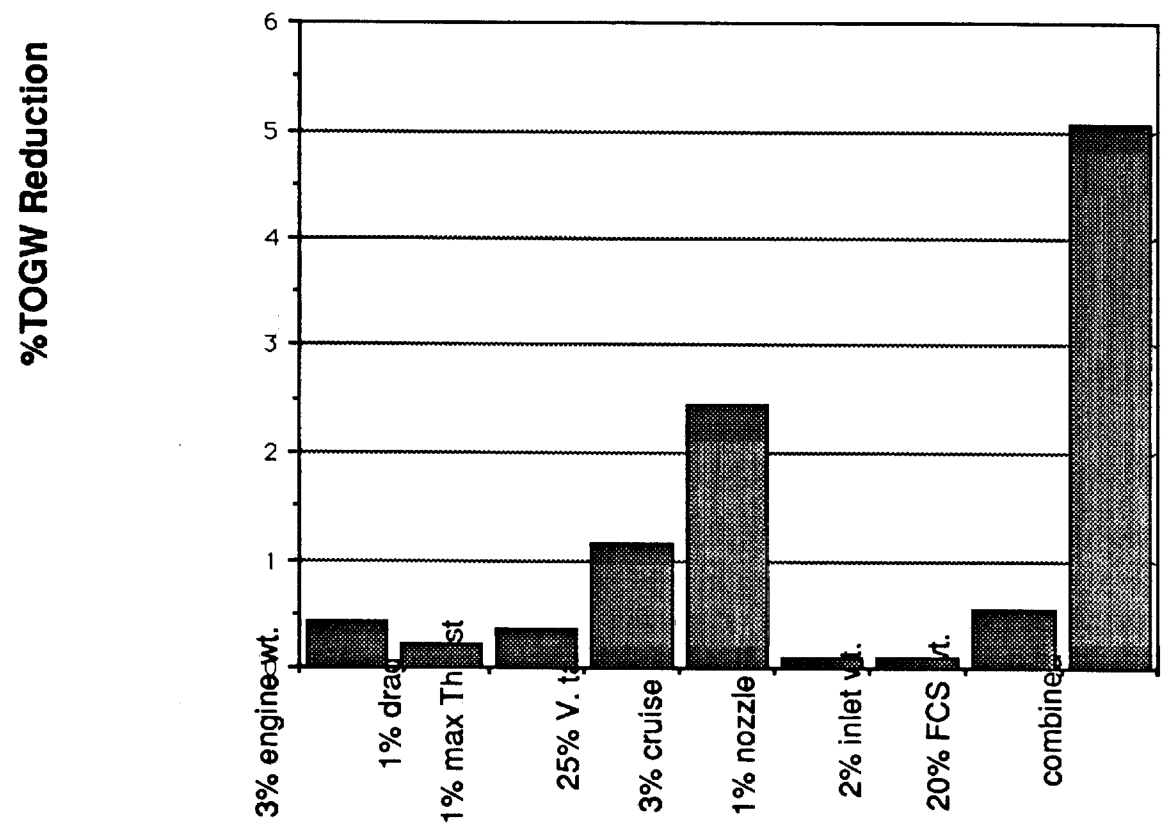
Sensitivity of HSCT Takeoff Weight to Airframe-Propulsion Integration



Systems Analysis Branch

In light of increased fuel prices over the last six months, it is of interest to examine the sensitivity of HSCT aircraft direct operating cost (DOC) to fuel cost. Is the sensitivity so high as to jeopardize the economic feasibility of HSCT aircraft? How does the sensitivity compare to that of subsonic transports?

This study compares the percent increase in DOC due to doubling the price of fuel for the Boeing 747-200, the Concorde, a Mach 1.6 delta configuration, and a Mach 1.6 oblique wing/body. The ACSYNT cost methodology was used to estimate the aircraft manufacturing costs and airline operating costs in 1990 dollars for a production of 400 aircraft. A fuel price of $0.60 and $1.20 per gallon was used and the utilization of each aircraft was fixed at 3500 hours per year. The 747 has twice and the Concorde half the number of passengers carried by the Mach 1.6 aircraft. Basic characteristics of the aircraft are:

Parameter	B747	Concorde	Delta	Oblique
Gross Weight	776058	399100	603849	529380
Passengers	412	108	200	200
Design Mach	0.84	2.0	1.6	1.6
For 3200n.mi Stage				
Block Time	7.2 Hr	3.7 Hr.	4.5 Hr.	4.5 Hr.

The results show that the DOC for the 747 increases 20%, for the Concorde over 30%, approx. 28% for the delta and 25% for the oblique wing. These results are preliminary and represent the very beginning of this study.

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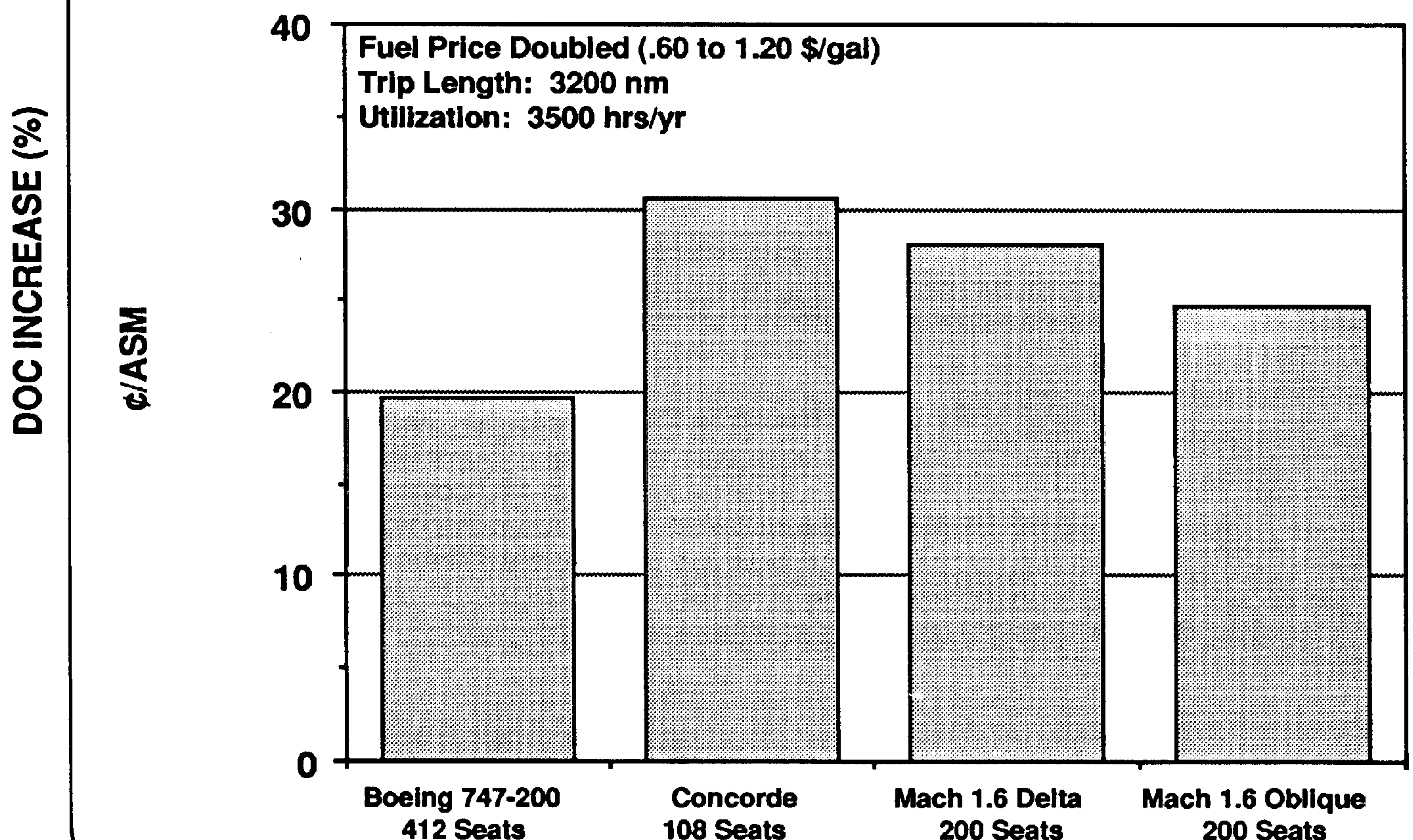
Fuel Price Sensitivity



Systems Analysis Branch

This is an ACSYNT-generated image of the Mach 1.6 oblique wing/body configuration that is being evaluated as part of an innovative concept study. It is based on a 1975 Boeing study for a transport cruising at Mach 1.2. The wing weight is based on that study and therefore is conservative with respect to today's technology level. The configuration has four engines mounted in the rear of the fuselage, two high and two low exhausting in the base area, with side-mounted inlets. The engines are the Pratt & Whitney TBE cycle.

This design was resized for Mach 1.6, as was the delta wing baseline that was derived from a 1988 HSCT design. Thus, the baseline aircraft technology levels were not the same and the results are conservative with respect to the oblique wing.

These results are preliminary and are subject to change. The wing/body analysis is a precursor to a follow-on oblique flying wing study.

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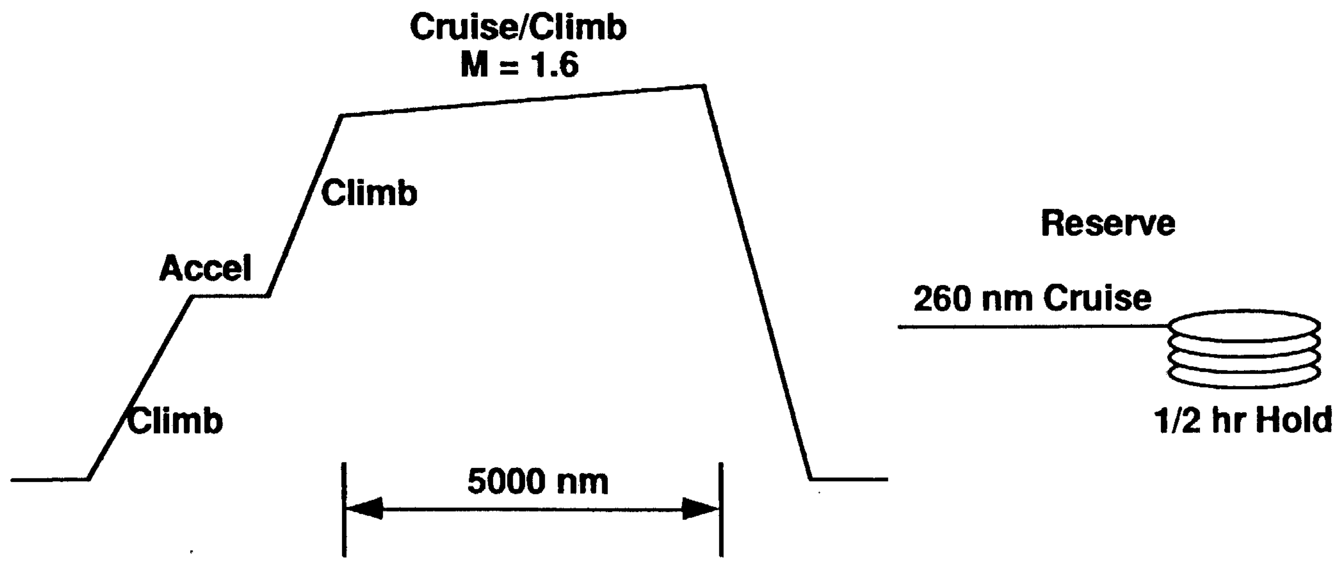
This figure shows the design mission for this study.

Oblique Wing
Initial Sizing Studies

Design Mission

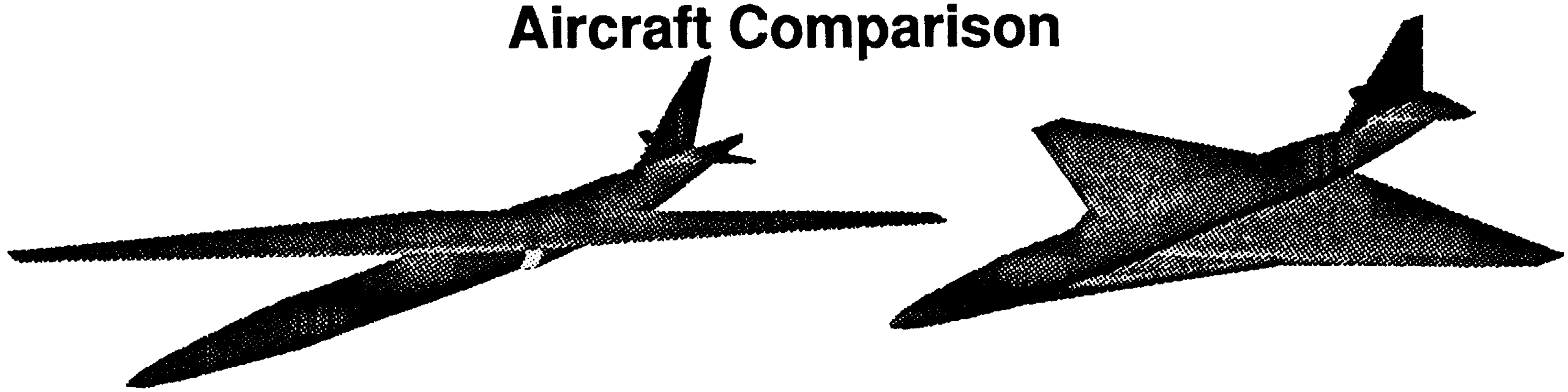


Payload = 200 Pass + baggage

This table shows a comparison of some key parameters for the oblique and delta configurations. The subsonic L/D for the oblique is higher for the oblique wing due to the higher aspect ratio and improved lift curve slope of the lower sweep oblique wing. The higher supersonic L/D of the oblique is due primarily to lower wave resulting from an improved cross-sectional area distribution..

The vastly improved takeoff and landing performance of the oblique comes from the improved low speed characteristics of an unswept wing.

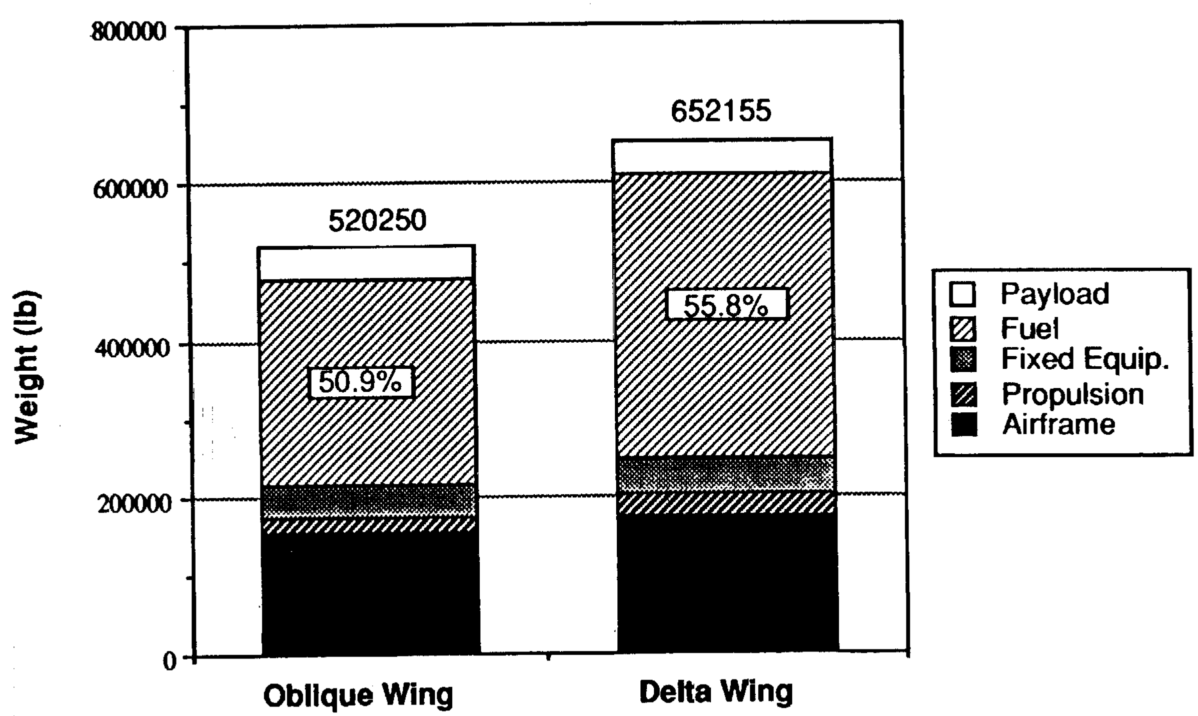
Aircraft Comparison



	Oblique Wing	Delta Wing
Gross Weight	520250 lb	652155 lb
Engine Thrust	31345 lb	49000 lb
Fuel Weight	265036 lb	364191 lb
Takeoff Length	6254 ft	8860 ft
Landing Length	5316 ft	10000 ft
Supersonic L/D	10.95	9.21
Subsonic Cruise L/D	16.0	13.0
Wing Area	4000 sq ft	5900 sq ft
Wing Span	174 ft.	128 ft.

This figure shows the weight breakdown for the two configurations. Two of the oblique wing's advantages are apparent here. First, the higher structural efficiency of the oblique wing results in much lower structural weights for the wing and fuselage. Secondly, the higher cruise L/D of the oblique wing results in improved fuel efficiency, and hence lower fuel requirements. These two effects, when integrated over the vehicle's design, results in a savings of approximately 20 percent.

Weight Breakdown



The Systems Analysis Branch at Ames Research Center has been involved in the HSR program for nearly a year. The majority of this activity has involved enhancements to the ACSYNT conceptual design synthesis program. These enhancements have centered on analyses of particular importance to HSR, including sonic boom, noise, and economics.

One limitation of these studies has been in the data available to represent current HSCT configurations. An effort will be made to correct this deficiency.

As shown, the fuel cost impact study and the oblique wing study are in the early stages and will be continued and completed in the coming months. Results will be released as appropriate.

Additional study activities of the branch will be assigned by the Systems Integration Steering Committee of the High-Speed Research Program. Ames will generally be responsible for economic studies, innovative concept studies, and parametric sensitivity studies.

Summary

- FIRST YEAR OF ACTIVITY HAS CENTERED ON CODE DEVELOPMENT AND LIMITED STUDIES
- ADDITIONAL DATA NEEDED FOR BASELINE CONFIGURATIONS
- FUEL COST IMPACT, OBLIQUE WING STUDIES TO BE CONTINUED AND COMPLETED
- OTHER STUDIES TO BE ASSIGNED BY SYSTEMS INTEGRATION STEERING COMMITTEE

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