OVERVIEW OF LANGLEY SYSTEMS STUDIES

SAM DOLLYHIGH

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WHY NASA SYSTEMS STUDIES?

SELF-EXPLANATORY

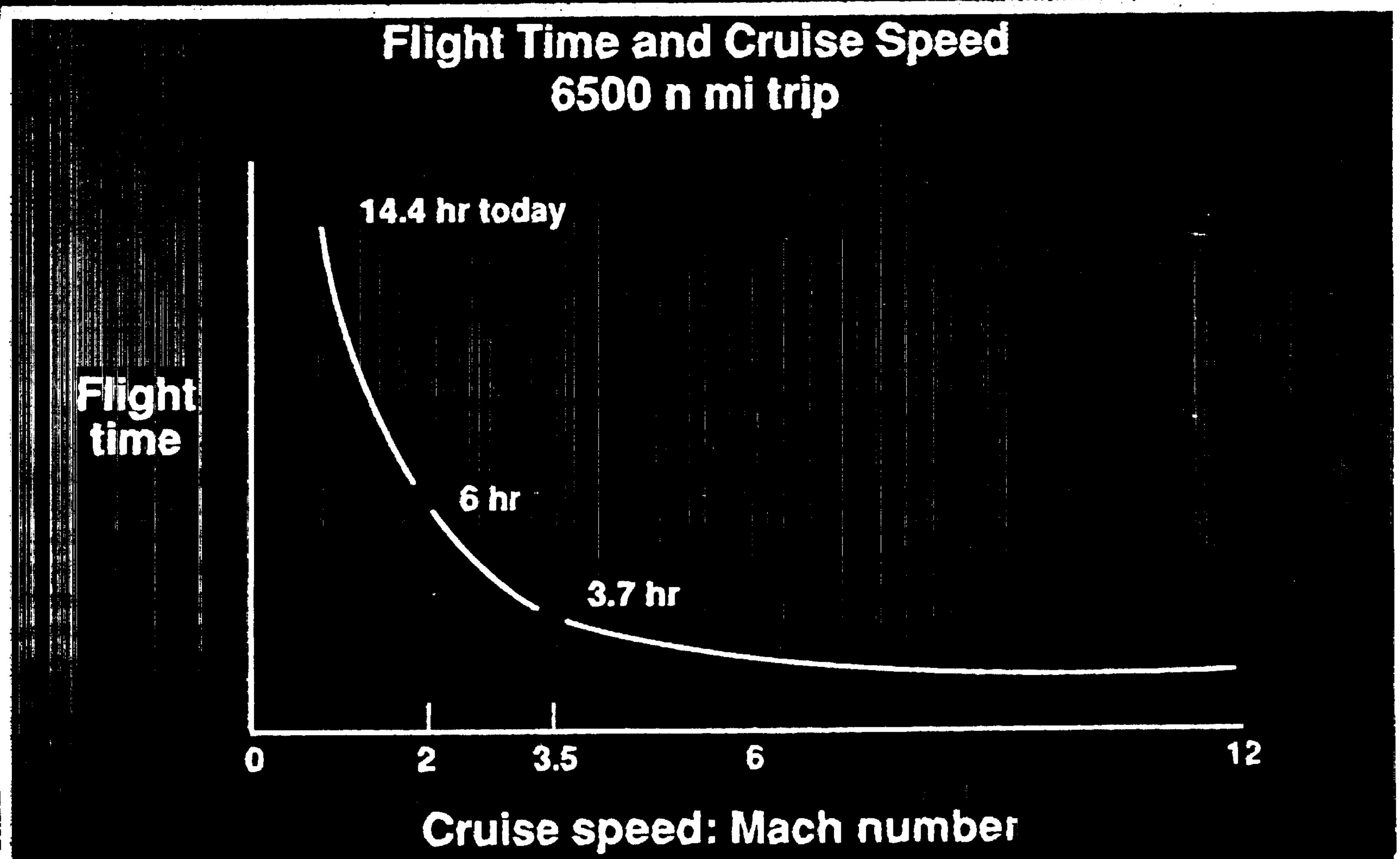
WHY NASA SYSTEMS STUDIES?

- ONLY AIRCRAFT SYSTEMS STUDIES CAN QUANTIFY THE OVERALL EFFECTS OF TECHNOLOGY STUDIES AND INDICATE VIABLE SOLUTIONS
- SYSTEMS STUDIES ARE NECESSARY TO PROVIDE INPUTS TO ASSESS COMMUNITY NOISE AND SONIC BOOM LEVELS
- PROVIDE CONTINUING FOCUS FOR TECHNOLOGY STUDIES
- IN-HOUSE STUDIES MAKE NASA A BETTER "CUSTOMER" AND REMOVE COMPANY BIASES
- MAJOR BENEFITS OF VEHICLE INTEGRATION STUDIES IN A RESEARCH INSTITUTION
  - -- Guide to Discipline Research
  - -- Technology Evaluation
  - -- Identification of High-Payoff Technologies
  - -- Foster Innovation
  - -- Identify Associated Research Required for Technology Application
  - -- Expedite Technology Transfer

CRUISE SPEED: MACH NUMBER

A good systems analyst will spend some time examining the question or problem before attempting to generate aircraft concepts in response to a set of requirements. This figure presents flight time versus cruise Mach number for an aircraft that experiences an average acceleration and deceleration of 0.2 g and has a range of 6500 n.mi. One does not need a series of aircraft concepts to generate such a curve, just a knowledge of physics. A simple aircraft mission performance program is useful to get the climb and descent times right. Based on this information, Langley decided to examine HSCT concepts in the Mach 2.0 to 4.0 range, which captures the knee of the curve. Mach 4.0 was chosen as the maximum for the in-house studies based on a desire to stay with turbojet propulsion systems. A tremendous jump in technical complexity occurs above Mach 4.0 and would most certainly be post year 2005 before commercial application. The nature of the curve of flight time versus Mach does not change rapidly with range and/or acceleration. Very large accelerations would be required to make the higher Mach numbers payoff. Note that for commercial application 6500 n.mi. range captures over 90 percent of the long range market so longer ranges hold relatively little commercial interest (it is simple geography and population location). Also, the average mission range in airline service is much less than the design mission, which further reduces the benefits of higher Mach numbers.

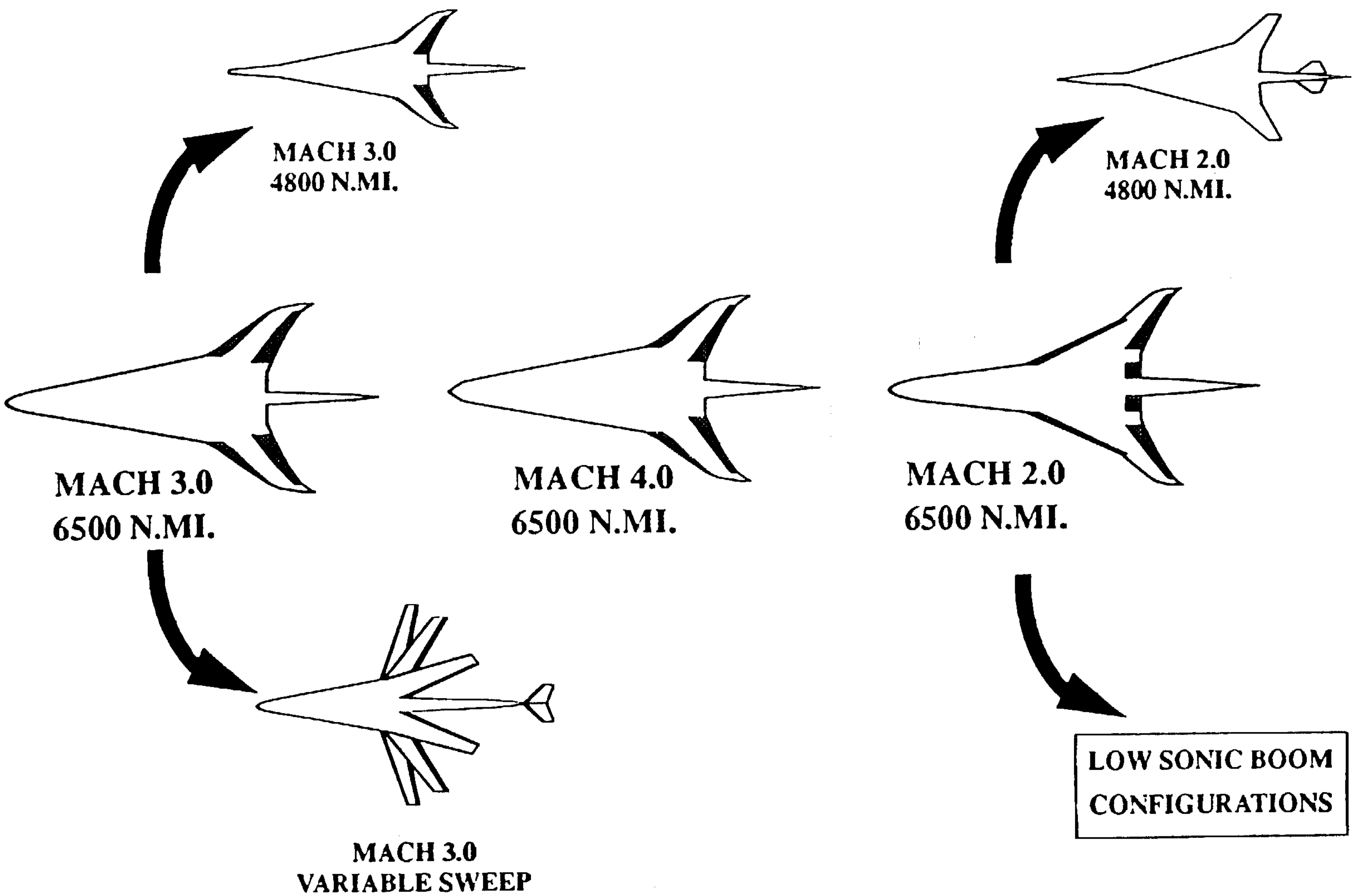
HIGH-SPEED CIVIL TRANSPORT



CONFIGURATION STUDIES 1987-1990

The progression of early configuration studies is illustrated in this figure. The Langley studies were initiated at Mach 3.0 to examine the technologies required to achieve reasonable range/payload characteristics. Mach 3.0 was chosen principally to be within the range of thermally stabilized Jet A (economic viability) aspects and as representative of a modest technological challenge. Next, the upper end of the Mach range of interest was studied with a Mach 4.0 concept. Using year 2015 technology projections, this concept was found to be too heavy, even before environmental issues were addressed. The lower end of the Mach spectrum of interest was then examined with the Mach 2.0 concept. The resulting takeoff gross weights of these concepts will be presented in the next figure. The effects of reduced range were determined on the Mach 2.0 and 3.0 concepts, but not on the Mach 4.0 concept since high speed and reduced range tend to be incompatible. A variable sweep Mach 3.0 concept was also studied in an attempt to resolve the need of good low-speed characteristics for takeoff, landing, and subsonic overland flight with good supersonic cruise efficiency. The results of this study will be discussed in more detail on subsequent charts. Although some low sonic boom configuration work was done at Mach 3.0, the primary focus of the vehicle systems studies on low-boom concepts has been Mach 2.0 and below.

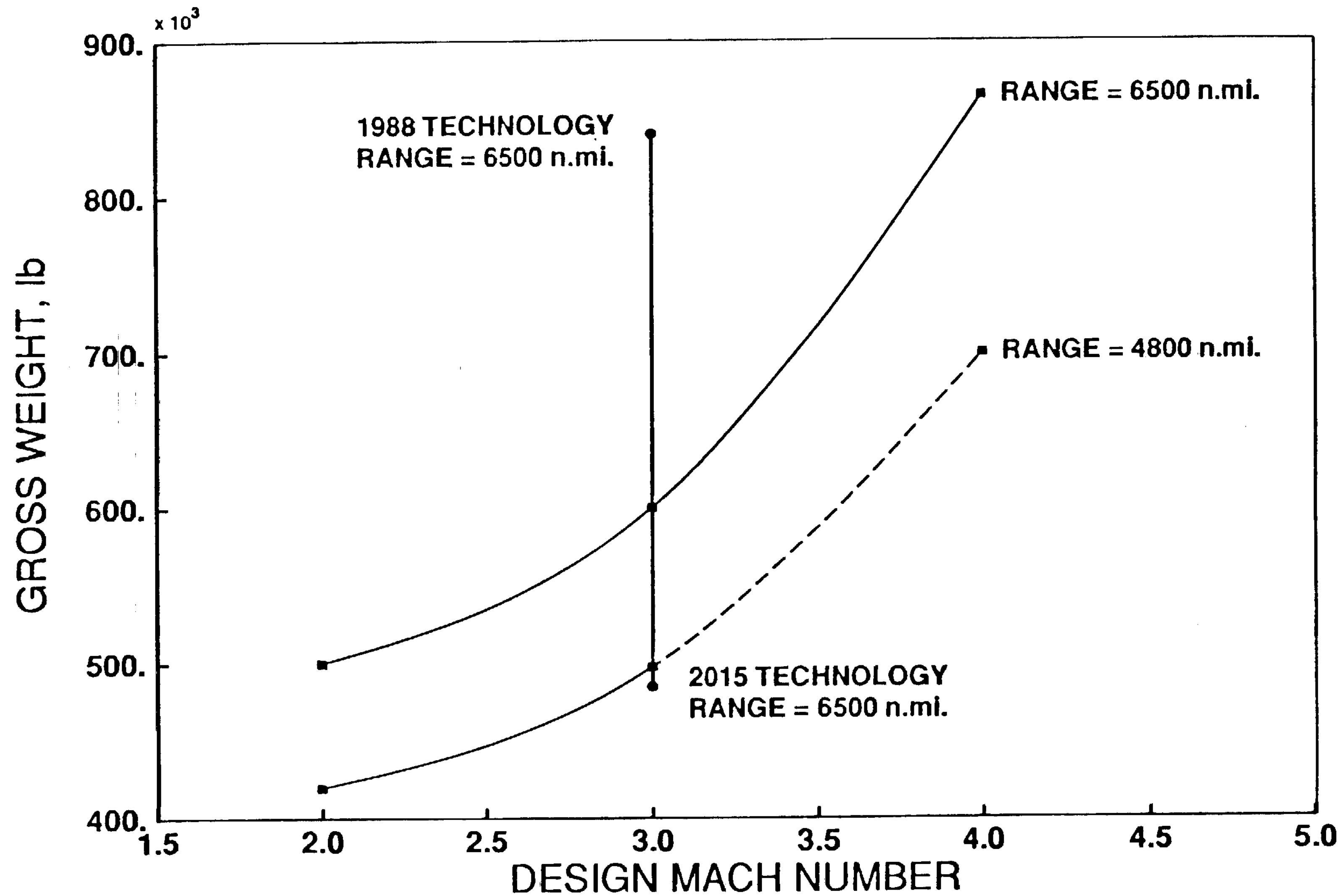
CONFIGURATION STUDIES 1987-1990



IMPACT OF DESIGN MACH NUMBER, RANGE, TECHNOLOGY

The resulting takeoff gross weights of the concepts over the Mach range from 2.0 to 4.0 are shown. At 6500 n.mi. range and utilizing an aggressive approach to year 2000 technology availability, the TOGW's vary from approximately 500,000 lbs. at Mach 2.0 to over 865,000 lbs. at Mach 4.0. (Stage III noise requirements are not fully met.) As Mach 2.0 is approached, the curve tends to flatten out and will probably increase slightly if lower Mach numbers are considered. Reducing range 26 percent to 4800 n.mi. tends to reduce TOGW about 16 percent (dashed portion of the curve from Mach 3.0 to 4.0 is extrapolated). The very large payoff of advanced technology to these type aircraft is indicated by the vertical line. At 6500 n.mi. range and Mach 3.0, using technology available in 1988, the TOGW would be over 840,000 lbs. A year 2000 technology airplane would be slightly over 600,000 lbs. and year 2015 technology availability could further reduce the TOGW to about 480,000 lbs. These weights reflect an assumption of that full achievement of goals associated with advanced technology are realized and tend to be lower than some HSR contractor weights, but the trends with range and technology availability match well whether the numbers are NASA or contractor generated.

IMPACT OF DESIGN MACH NUMBER, RANGE, TECHNOLOGY



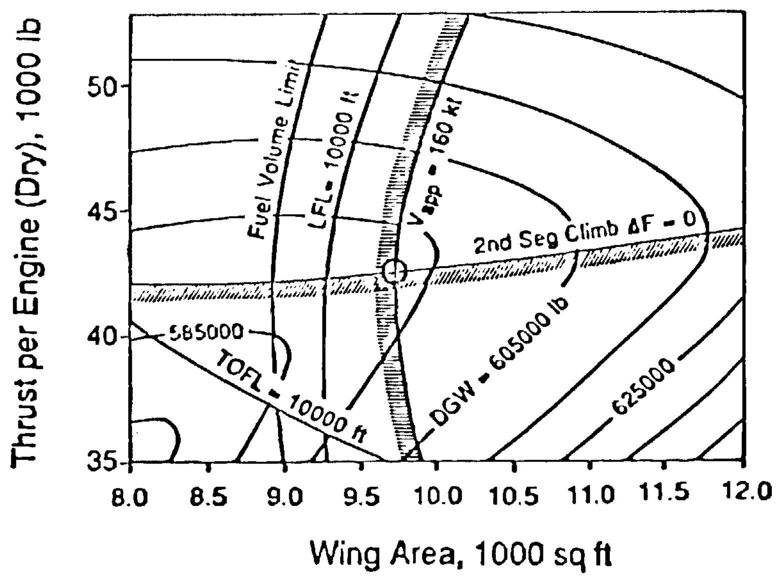
ENGINE AND WING SIZING

Mach 3.0 Concepts

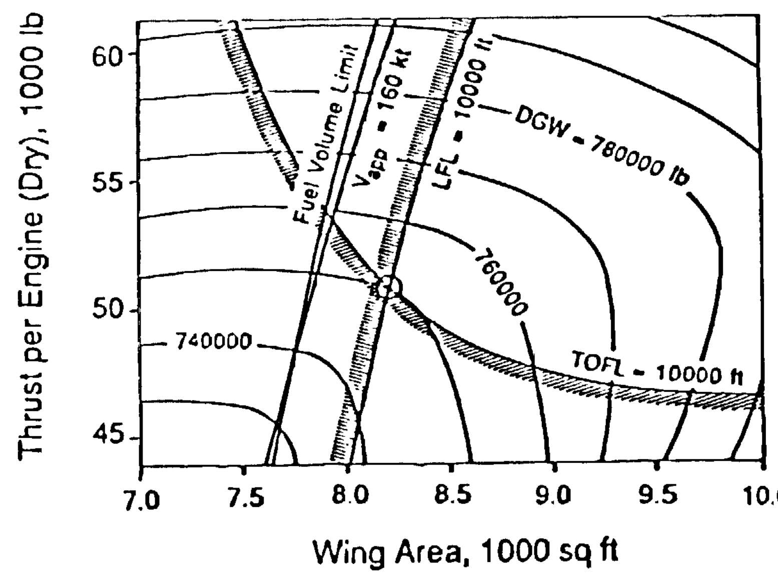
The Mach 3.0 variable sweep concept was examined in an attempt to improve the high subsonic cruise performance for overland flight as well as improve takeoff and landing performance. Unless successful low sonic boom concepts can be developed, a longer range HSCT will require good subsonic characteristics for its overland leg. Shown in this chart are the sizing thumbprints for the fixed wing and variable sweep concepts for a 6500 n.mi. all supersonic mission. The fixed wing concept sizes to about 600,000 lbs. by the requirements that approach speed with 3/4 fuel load be less than 160 knots and that second segment engine out climb gradient be met. Takeoff thrust-to-weight ratio is about .28 and wing loading 61 lbs./ft^2. The variable sweep airplane is sized to 750,000 lbs. and is constrained by landing field length and takeoff field length. Takeoff thrust-to-weight and wing loading are approximately .27 and 91 lbs/ft^2, respectively. Although the switch in sizing constraints indicate superior low-speed performance for the variable sweep airplane, its overall weight is greatly increased for an all supersonic mission due to difficulty in packaging the configuration to achieve a low drag concept and the additional weight associated with the pivot. The effect of sizing the two concepts for mixed subsonic/supersonic mission legs is shown on the next figure.

ENGINE AND WING SIZING

Mach 3.0 Concepts



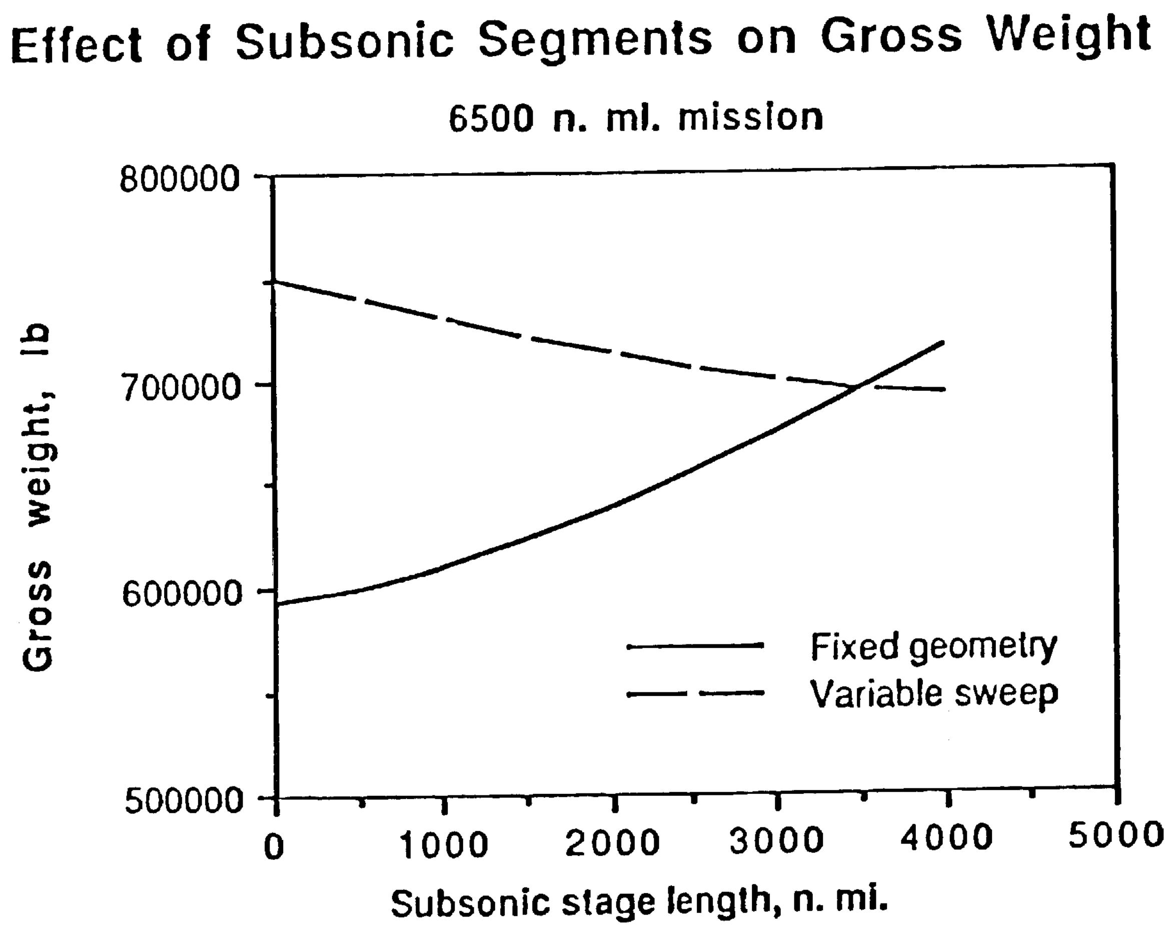
Fixed Wing



Variable Sweep Wing

EFFECT OF SUBSONIC SEGMENTS ON GROSS WEIGHT

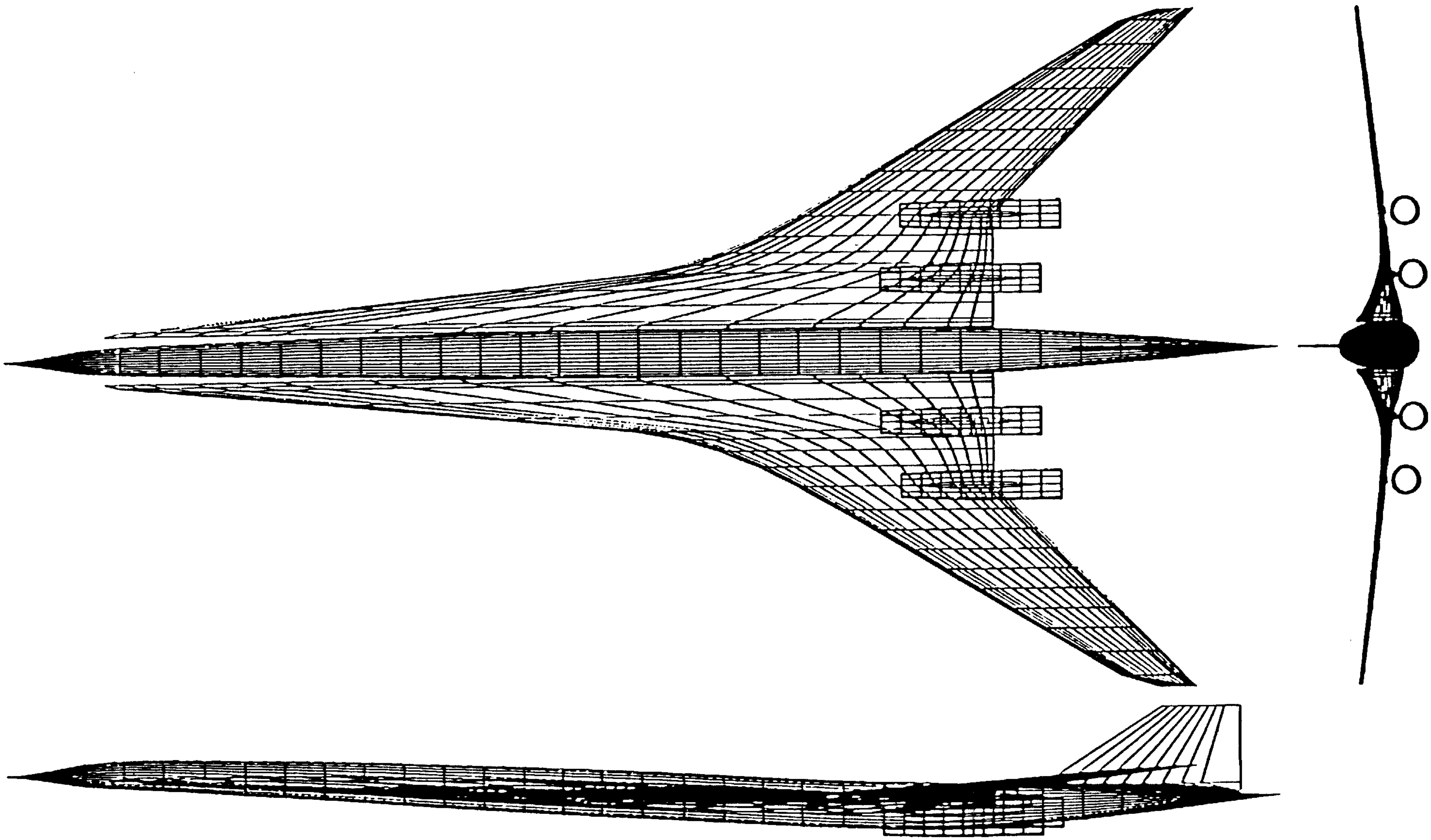
The resizing of the fixed geometry and variable sweep concepts to meet 6500 n.mi. range with different subsonic stage lengths is shown in this figure. The improved subsonic aerodynamic efficiency of the variable sweep concept cannot overcome the initial large weight penalty until the airplane flies over half its mission at subsonic speeds. Although the variable wing sweep shows little promise for this Mach 3.0 application, it should not be completely dismissed. It may show more promise at a lower Mach number application and even more promise if altitude restrictions are imposed. Good low-speed performance with a wing sized for altitude-restricted supersonic cruise will be a difficult design situation with a fixed wing.


Effect of Subsonic Segments on Gross Weight
6500 n. mi. mission
800000
700000
600000
500000
Gross weight, lb
0
1000
2000
3000
4000
5000
Subsonic stage length, n. mi.
Fixed geometry
Variable sweep

MACH 1.6 LOW-BOOM CONCEPT

The next two figures show the progress being made in designing low sonic boom concepts. This figure shows the numerical model of a Mach 1.6 concept currently under study. Low boom design requires long smoothly integrated wings so that the overall disturbance generated by lift and configuration volume meet the desired requirements for low boom. The configuration shown is the result of several iterations with emphasis on keeping wing aspect ratio in line with that of performance concepts without sonic boom considerations. The concept is currently undergoing a complete system analysis. Low speed stability and control will probably dictate the need for a canard which may pop out at subsonic speeds or may be fixed and simply be flown unloaded at supersonic speeds. The more detailed studies being conducted will provide the better systems analysis solutions in terms of volume utilization, weight, and drag and the resulting overall effect on mission performance to this and other issues.

MACH 1.6 LOW-BOOM CONCEPT

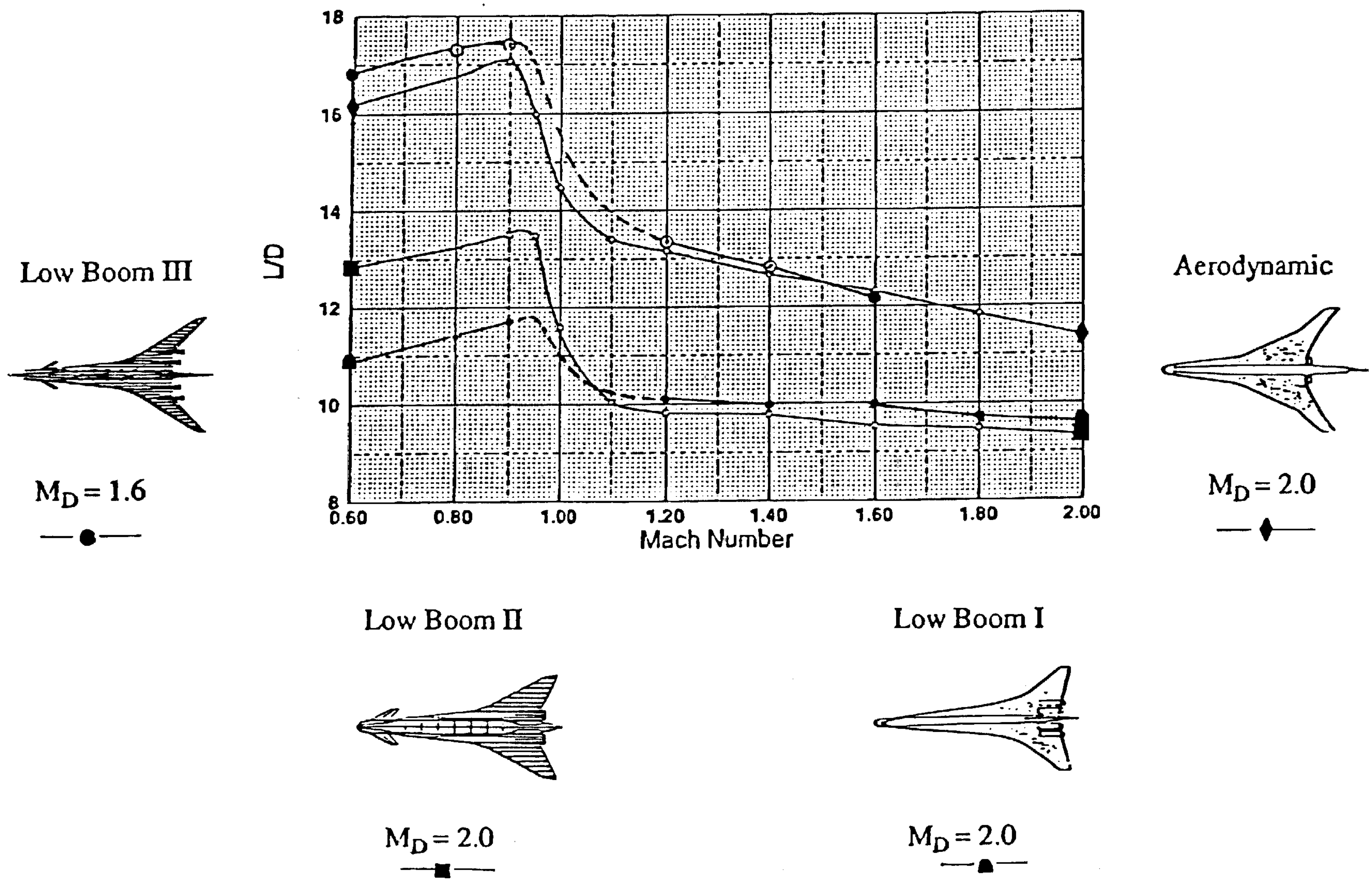


MAXIMUM L/D COMPARISONS

This figure shows the progress toward achieving low boom concepts with acceptable aerodynamic performance. The two earlier low boom concepts shown at the bottom suffered an across the speed range aerodynamic penalty in comparison to the configuration shown on the right which has no sonic boom requirements imposed. The low-boom configuration discussed in the previous figure (shown on the left) compares favorably with the configuration designed for aerodynamic performance. However, the caveat under the title that low-boom configuration is untrimmed gives a good indication of the work remaining before success is declared. Nevertheless, good progress is being made in achieving low sonic boom concepts with aerodynamic characteristics that compare favorably with concepts without sonic boom constraints.

MAXIMUM L/D COMPARISONS

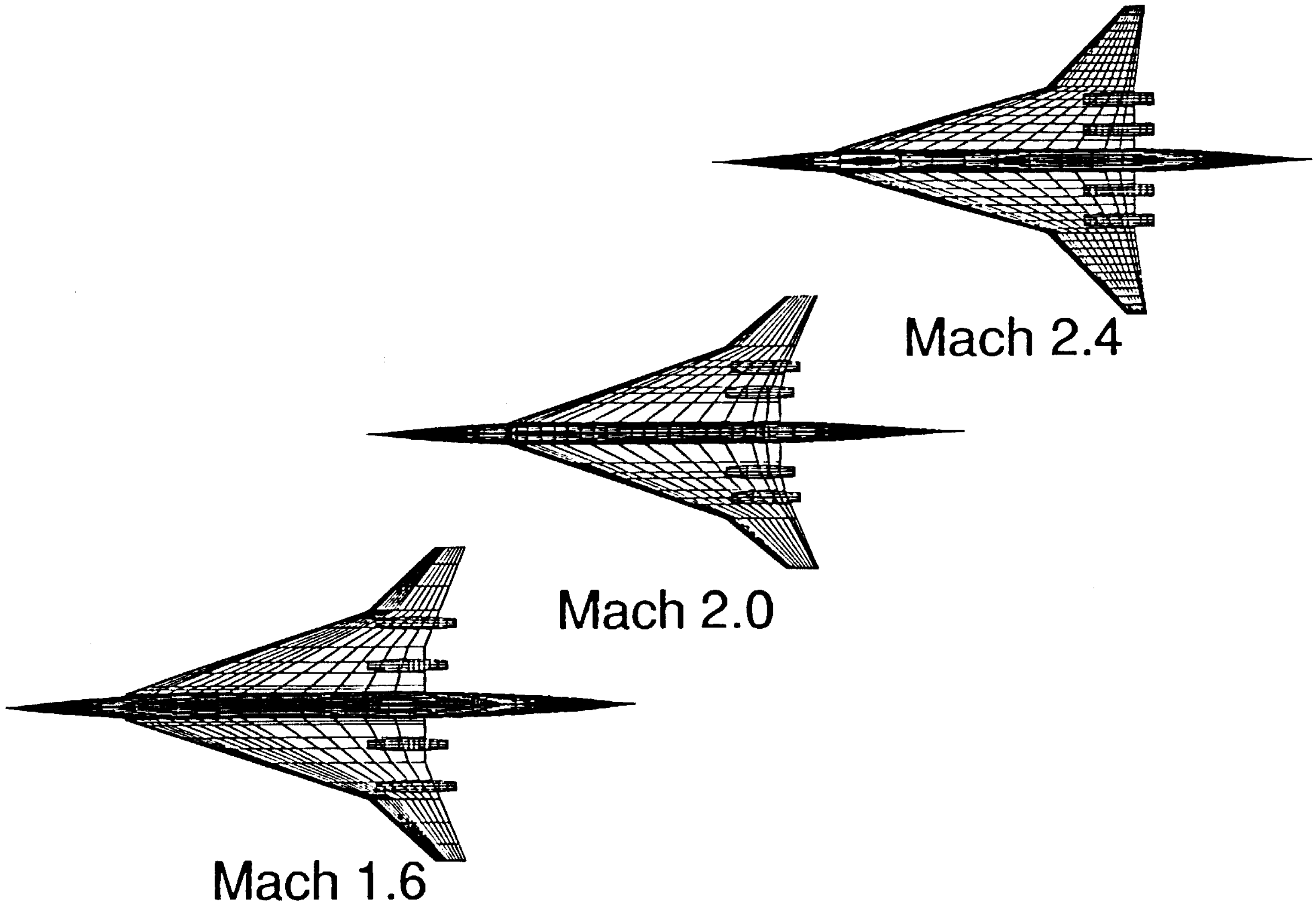
Aerodynamic Configuration Trimmed; Low-Boom Configurations Untrimmed.



LANGLEY BASELINE CONCEPTS AS OF MAY 15, 1991

Late in 1990, the NASA Systems Integration Group began functioning and the aircraft systems studies entered a second phase. This group proposed tightly coordinated Ames/Langley/Lewis/Industry studies that would address a series of tasks to evaluate progress, recommend appropriate direction and emphasis changes in technology elements based on system-level payoffs and potential success assessments. Based on technical and economic assessment studies of HSCT's to date, Mach 2.4 was chosen as the primary focus for the High-Speed Research Program (HSRP) with Mach numbers 2.0 and 1.6 being backups in case of technology shortfalls. The current NASA Mach 1.6, 2.0, and 2.4 baseline concepts are shown in this figure. The concepts are not as highly integrated as the previously discussed concepts and will suffer a little in overall performance compared to a highly-integrated well-blended configuration. However, these generic concepts are easy to redesign or resize so as to evaluate technology and design options being proposed as part of HSRP. Highly integrated concepts tend to have little flexibility for other than small geometry changes. Several unanticipated problems arose in the design of the concepts. It was expected that the Mach 1.6 concept could have the inboard wing section unswept 12° and 13° with respect to the Mach 2.4 concept. However, the combination of lower wing sweep and lower Mach angle resulted in a configuration that was virtually impossible to area rule for wave drag, so wing sweep was maintained to get the desired aerodynamic efficiency. Also, the lower shock angle required the engines be spaced further apart to prevent mutual unstart. The Mach 2.4 concepts reflects some ongoing design trades with low-speed aerodynamics and structures, that have not been incorporated into the two lower Mach number concepts. All three concepts are generic in nature and will be used to answer such questions such as the fundamental trades between wing sweep, drag, low-speed aerodynamics, wing weight, stability and control, and so on. The consequences of cruise altitude restrictions will be examined on the 1.6 concept, as well as the application of advanced materials as a function of Mach number.

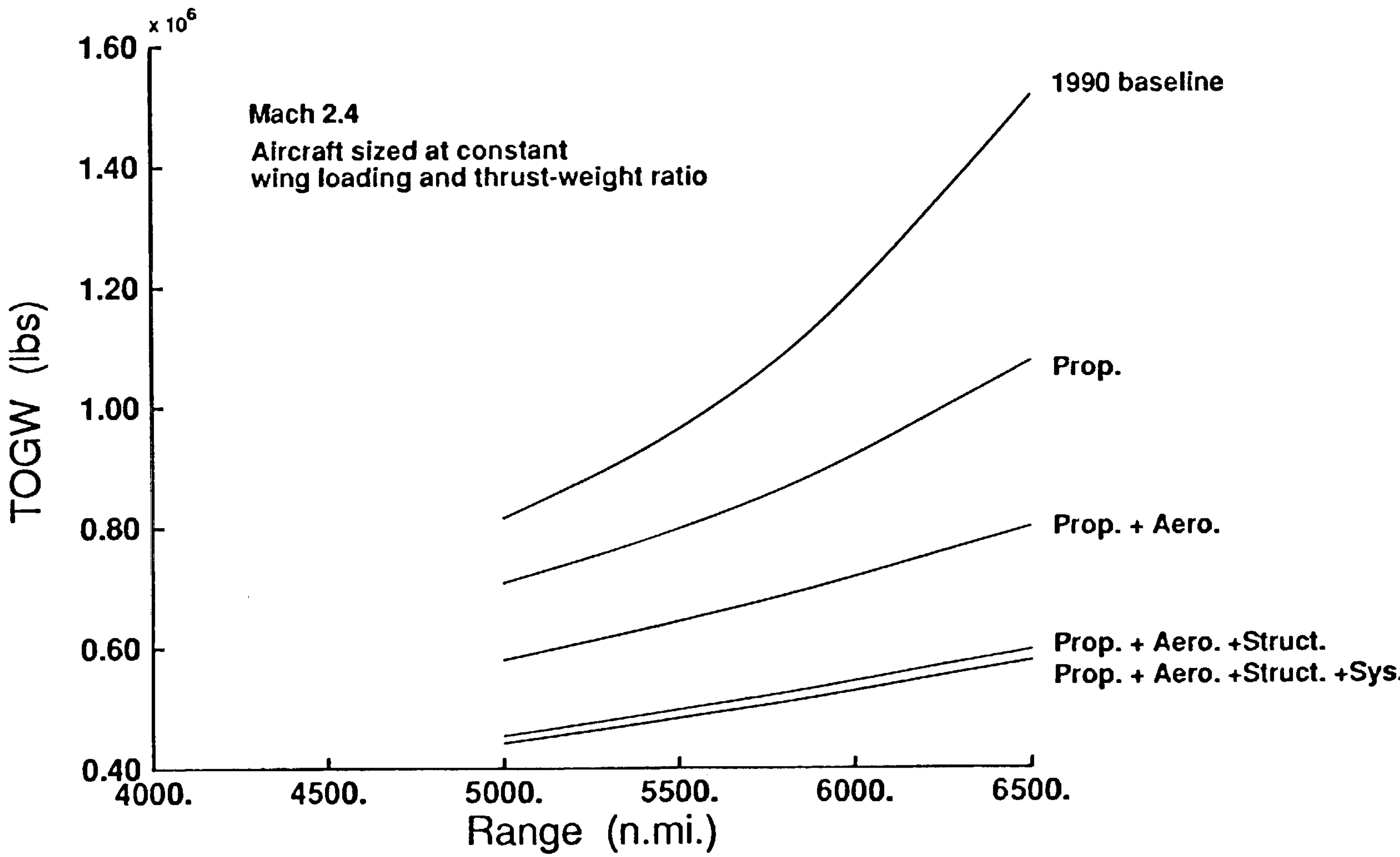
LANGLEY BASELINE CONCEPTS AS OF MAY 15, 1991



HSR TECHNOLOGY CHALLENGE

The payoff of meeting the technology goals established for the Phase II HSRP are shown in this figure for the Mach 2.4. 250 passenger concept. The individual technology goals associated with each discipline will be discussed in a following chart. The overall message is strong and clear that advanced technology has a tremendous payoff when applied to this type vehicle. Today's technology will barely support a reasonable size HSCT with a range of 5000 n.mi. If 100 percent success is achieved within the HSR technology program, the vehicle weight could be reduced approximately 45 percent at a constant range or be traded to achieve longer range with competitive sized aircraft. Cautionary note: These are sizing trends that indicate the maximum payoff. Detailed design of a configuration at each point will probably result in less than the maximum payoff indicated.

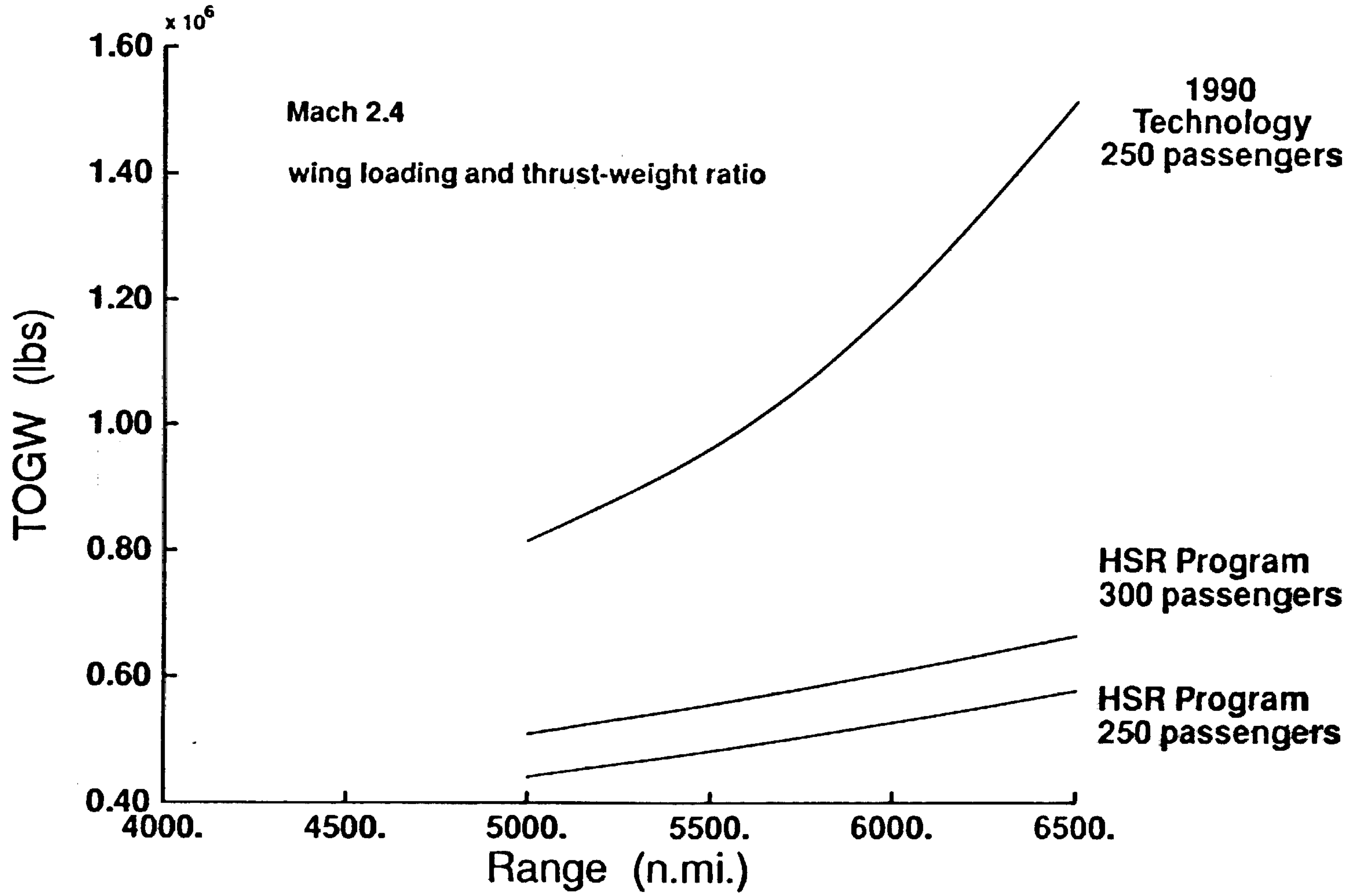
HSR TECHNOLOGY CHALLENGE



HSR TECHNOLOGY CHALLENGE

Since the objective of a commercial airplane is to achieve a satisfactory return on investment, a more likely payoff associated with advanced technology is shown. Instead of continuing to reduce weight, passenger payload and range will be increased. The figure shows that from an 800,000 lb., 5000 n.mi. range 1990 technology airplane, the full realization of the payoffs associated with Phase II HSR technologies would enable a range increase of 1500 n.mi. with a passenger increase of 50 and still reduce takeoff gross weight by over 10 percent. Longer range and more passengers translates directly into increased revenue passenger miles and increased return on investment.

HSR TECHNOLOGY CHALLENGE

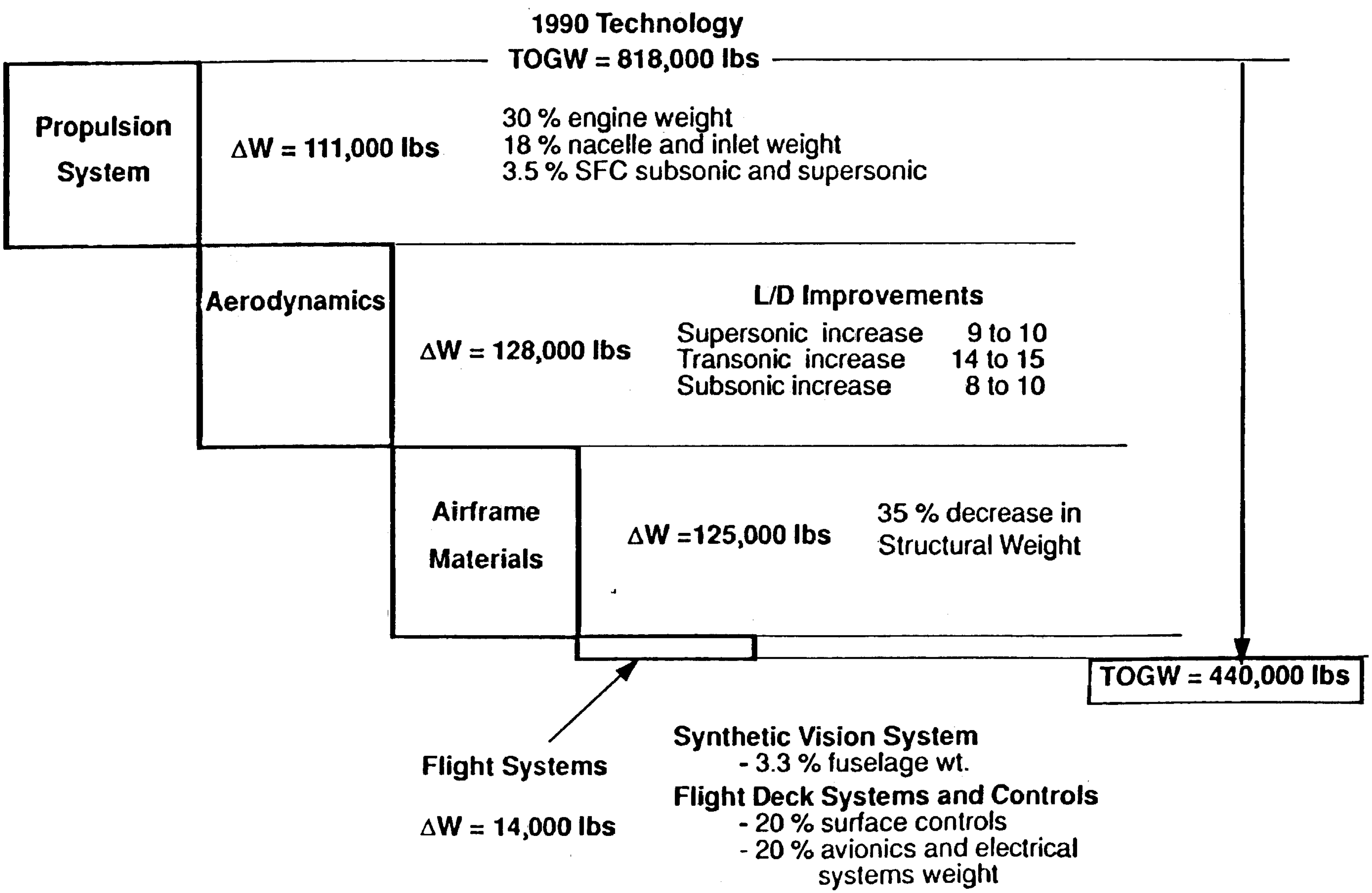


HSR TECHNOLOGY OPPORTUNITIES

More details of the HSR technology opportunities are shown in this figure. The technology improvements shown are the expected result of the HSR Phase II Program or the adaptation of other applicable technologies such as propulsion materials from the Air Force's Integrated High Performance Turbine Engine Technology (IHPTET) Program. Again, these technology improvements are for a 2005 IOC relative to 1990 technology availability. An expected improvement of 30 percent in engine weight, 18 percent in nacelle and inlet weight, and 3.5 percent in SFC results in a takeoff gross weight reduction of 111,000 lbs. (14%). Achieving supersonic cruise, transonic and takeoff L/D's of 10, 15 and 10, respectively, further reduce TOGW by 128,000 lbs (16%). Advanced materials and structures which reduce the structural weight by 35 percent are worth 125,000 lbs. (15%) savings in TOGW. Synthetic Vision Systems to eliminate dropping the nose at takeoff and landing conditions and weight savings from advanced systems and controls save about 14,000 lbs. (2%) in TOGW. Weight savings associated with advanced controls, such as active controls for flutter and load alleviation, and integrated airframe/propulsion controls that reduce fuel burn have been bookkept under the discipline improved by the flight control system. The bottom line is that all disciplines have very significant contributions to make in developing an economically viable HSCT. Again, most of these huge weight savings would be traded for longer range and higher payload to increase economic competitiveness.

HSR TECHNOLOGY OPPORTUNITIES

Mach 2.4 cruise 5000 n.mi. range 250 passengers



LONG-TERM MULTIDISCIPLINARY AIRFRAME INTEGRATION STRATEGY

Langley Research Center has established an interdisciplinary team to strengthen the multidisciplinary aspects of aircraft design and analysis. The vehicle focus of this team is the HSCT, although the resulting methodology and data management system will be applicable to other aircraft types. Experience indicates that methods development of this type are best accomplished and are applied if they are developed in response to a real programmatic need rather than generically. This figure indicates the long-term strategy for the High-Speed Airframe Integration Research (HiSAIR) project. The first step was to establish or reestablish discipline interfaces that are state-of-the-art in terms of that enabled by today's engineering workstations and computer networks. Two areas requiring much attention were the development of geometry methods that would permit rapidly modeling airplane concepts for first-order as well as higher order analysis by the various disciplines and the development of a data management system. Currently, modeling for higher order methods can take as long as two months, even starting with numerical models acceptable for first-order analysis. We think we can cut that time to one or two days. A data management system that permits data transfer between disciplines without an overhead burden on the discipline expert is being put together. The project is moving into the second phase of limited optimization. This phase will establish the methodology for rigorous optimization via discipline sensitivity derivatives for a baseline vehicle. The longer range (approximately 5 years) goal is to develop a system that permits full multidisciplinary coupling and optimization. Langley is anxious to interact with company aircraft design teams and advanced design organizations to enhance the value of this work. Again, the vehicle focus of HiSAIR is the HSCT and it is being used to develop the Mach 1.6, 2.0, and 2.4 NASA study concepts. In addition to strengthening discipline research, one result of HiSAIR will be a higher level of fidelity in Langley's vehicle systems studies.

LONG-TERM MULTIDISCIPLINARY AIRFRAME INTEGRATION STRATEGY

Establish Discipline Interfaces → Limited Optimization → Full System Optimization

Establish Discipline Interfaces

- Geometry
- Data Transfer

Limited Optimization

- Discipline sensitivities established around vehicle baseline

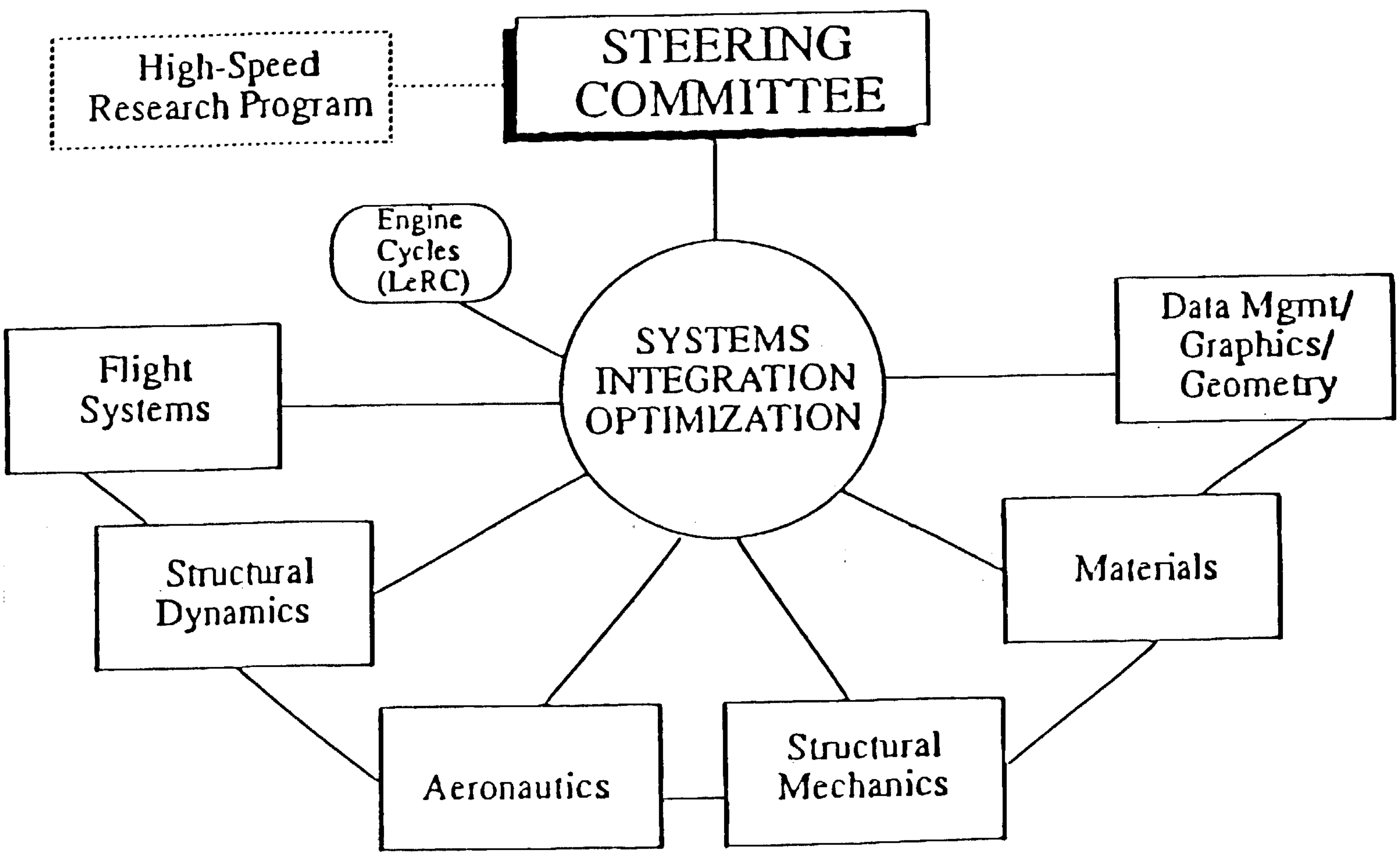
Full System Optimization

- High performance computing initiative

HIGH-SPEED AIRFRAME INTEGRATION RESEARCH MANAGEMENT

The HiSAIR project cuts across four directorates at Langley and has geometric methods development in common with a fifth. A Steering Committee of Division Chiefs sets policy and direction. Systems integration and optimization as performed by the Vehicle Integration Branch, Advanced Vehicles Division, and the Interdisciplinary Research Office, Structural Dynamics Division, are the controls for the activity. Engines are supplied by Lewis Research Center, and eventually Lewis's efforts in propulsion system design methods and Langley's HiSAIR will be formally coupled. Discipline experts from the functional areas shown around the figure make up the HiSAIR team.

HIGH-SPEED AIRFRAME INTEGRATION RESEARCH MANAGEMENT



HIGH-SPEED AIRFRAME INTEGRATION RESEARCH

Status

The status of the HiSAIR activity is shown on this figure. In addition to the points on this figure, the real value of HiSAIR for Langley is the strengthening of disciplinary research within vehicle focus programs. This strengthening occurs through an understanding of the multidisciplinary application of technology to a vehicle system. Technology transfer and value is enhanced by research and data bases more in line with how the aircraft industry will eventually apply the research.

HIGH SPEED AIRFRAME INTEGRATION RESEARCH

STATUS

- Full Time Manager ; 30 Professionals (most part-time)
- Performed High Level Analysis of High-Speed Civil Transport
- High Priority on Developing Numerical Modeling Techniques
- Data Management System Coming Together
- Concurrent Development of Optimization Methods
- HiSAIR Being Used to Design In-House Baseline Concepts in Support of HSR Program

NASA HIGH-SPEED RESEARCH PROGRAM

CONCLUDING REMARKS

SELF-EXPLANATORY

CONCLUDING REMARKS

- EARLY HSCT STUDIES FOCUSED ON TURBOJET POWERED AIRCRAFT
- VARIABLE-SWEEP WING CONCEPT REQUIRES 50/50 SUBSONIC/SUPERSONIC TO PAYOFF FOR MACH 3.0 CONCEPT
- GOOD PROGRESS IN LOW-BOOM CONCEPTS
- CURRENT EMPHASIS ON "GENERIC" CONCEPTS TO FACILITATE TECHNOLOGY TRADES
- SYSTEMS STUDIES REQUIRED TO ANSWER "IS IT AN AIRPLANE YET?"

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