NASA Contractor Report 3900

Study on Needs for a Magnetic Suspension System Operating With a Transonic Wind Tunnel

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SECTION 1.0
INTRODUCTION

A primary element of NASA's mission is to develop and operate advanced wind tunnel testing facilities in support of the U.S. aerospace industry and to provide research, development, and program support to U.S. government agencies. One of the current efforts to fulfill this mission is a program to develop a practical magnetic suspension and balance system (MSBS) that will eliminate the need for mechanical model support systems and mechanical force and moment measuring systems.

The current study is part of a comprehensive effort designed to meet the magnetic suspension and balance system program goals. Other elements include relocation of two small-scale research magnetic suspension systems to Langley Research Center with subsequent activation and use in research, a cooperative research and development program between Langley Research Center and the University of Southampton using an operational system, and full-scale system conceptual design studies.

The objective of the current study was to survey the U.S. aeronautical industry to determine if current and future transonic testing requirements are sufficient to justify continued development work by NASA on magnetic suspension and balance systems. A large body of published work exists documenting support interference problems in past wind tunnel test programs (References 1 and 2). The focus of the present survey was on current and future support interference problems and how they might be alleviated by the MSBS. Specifically, will the research and development program directed toward a large-scale MSBS for a large-scale transonic wind tunnel meet the needs of industry when completed?

The effort involved preparation of a brief technical description of magnetic suspension and balance systems, design of a survey form asking specific questions about the role of the MSBS in satisfying future testing requirements, selecting nine major aeronautics companies to which the description and survey forms were sent, and visiting the companies and discussing the survey to obtain greater insight to their response to the survey. The present report includes evaluation and documentation of the survey responses and recommendations which have evolved from participation in this study.

SECTION 2.0
PROCEDURE

2.1 MSBS DESCRIPTION

The primary component of the present study was a survey of industrial wind tunnel users. A brief description and history of magnetic balance and suspension systems addressing both the technical features and projected and proven applications of the system was developed to inform survey recipients who were not familiar with the MSBS. A brief description of key points follows.

Magnetic Suspension - What It Is and How It Works

Magnetic suspension is a technique which has been used for over 25 years to support models and measure aerodynamic forces acting on the models in wind tunnel flows. The primary application to date has been to determine static stability and drag coefficients of aircraft and missile configurations without support interference effects. Eleven magnetic suspension systems in the United States and Europe are known to have been successfully applied to small-scale wind tunnels with test sections up to 13 inches in diameter and speed ranges from subsonic to hypersonic.

The technique relies on the use of interacting magnetic fields and gradients in fields to produce forces and moments on the model. These forces:

- suspend the model within the test section (counteract gravity)
- offset aerodynamic forces and moments acting on the model to maintain a stable testing attitude
- permit controlled movement of the model within the test envelope

Measurement of the currents in each of the supporting electromagnetic coils is one of the methods which can be used to accurately determine the aerodynamic forces and moments acting on the model.

The magnetic suspension technique uses a magnetic core enclosed within a model which is energized to saturation by a magnetic field. Since like poles of magnetic fields repel and unlike poles attract, a strong rotating force or torque is applied to the magnetic core if it is placed in a separate applied field. The magnitude of the torque is proportional to the product of the magnetizing and applied fields acting in the plane of the applied field. The only way the magnetized core can experience a net force in addition to the torque is if the applied field is nonuniform in the direction of the desired force. It is evident that full control in six degrees of freedom requires a number of separate magnetic coils producing gradient fields in three dimensions.

Recent studies for NASA (References 3 and 4) show that a practical magnetic suspension and balance system can be developed for large transonic tunnels (2.5 x 2.5m test section) which:

- utilize magnet coils whose field strength, current, conductor size, and heat generation/dissipation are within current superconducting magnet technology
- produce forces and torques consistent with high-lift maneuvering flight of winged vehicles even in high Reynolds number transonic flow
- permit precise measurement of aerodynamic forces and moments
- can be acquired for a capital expenditure of 25 to 75 million dollars

Ten separate magnet coils would be used to suspend and control the model. The position and attitude of the model within the test volume would be determined by a combination of electromagnetic and optical position sensors. These analytical studies reveal that forces and moments can be measured with comparable, or even improved, precision when compared to that possible using current strain gage technology.

A number of factors remain to be demonstrated in moderate scale technology demonstration experiments prior to proceeding to a large scale application. These include:

- accuracy of position sensing consistent with three-dimensional motion analysis
- telemetry of on-board data from the model
- realizable accuracy in force and moment measurements consistent with requirements for performance analysis of advanced aircraft
- operational reliability of the system and overall productivity of data

Favorable resolution of these technical questions is a prerequisite for a large-scale MSBS effort.

Proven and Possible Applications

Successful testing of advanced aerodynamic configurations in current wind tunnels can only be accomplished if the data is corrected for recurrent support interference effects. The technical literature (References 1 and 2) includes hundreds of examples of support interference effects and the difficulties experimenters encounter in deriving corrections on almost every new program. These effects compromise both static stability and performance determination.

The classical support interference problems of:

- altered model geometry
- distorted airflow over the model
- distorted airflow behind the model

as well as other support-related constraints such as:

- limited static motion (X, Y, Z, and angle) with each physical setup which necessitates extra test hardware and repetitive testing
- limitations in achieving combined attitudes
- limited amplitudes and frequencies for dynamic stability testing without unacceptable sting oscillations

can be effectively eliminated with the magnetic suspension and balance system. Test program costs--model, tunnel occupancy, data reduction--remain to be evaluated relative to this enhanced testing capability.

Testing of multiple body separations (e.g., stores, crew escape modules, vehicle staging) could easily be accomplished with the MSBS without the numerous problems of multiple support systems which are routinely encountered using conventional techniques. The high nose-down pitch rate of the empty fuel tank on the F-16 during the ejection sequence could not be adequately simulated with the conventional captive trajectory support system or either heavy- or light-scaling free-drop techniques. Similar problems were encountered in testing the B-1 crew escape module ejection. Both problems were the result of interactions between the primary and secondary support systems. These and other store separation and two-body staging problems could be studied using the MSBS.

Experience shows that other less predictable benefits could arise if this important new testing technique becomes available such as:

- improved insight into high angle-of-attack performance
- improved wind tunnel productivity through the elimination of repetitive test setups
- simultaneous static and dynamic stability testing
- reduction in data analysis and corrective requirements

These factors might even offset added costs inherent in the use of the MSBS. In addition, it is likely that support interference effects will become more critical as:

- Reynolds number is increased in newer transonic tunnels such as the National Transonic Facility (NTF)
- wall interference is decreased using advanced wall designs
- aircraft develop in sophistication

NASA's MSBS Plans

NASA is presently conducting system development research with MSBS test units at Langley and the University of Southampton. A number of full-scale system configurations studies have been completed to define magnet types and arrangements, control unit types and control philosophy, model position sensing systems, calibration techniques, and auxiliary equipment requirements. The most recent of these studies (References 3 and 4) revealed no fundamental engineering limitations for a system compatible in size or scale with large transonic tunnels similar to NTF. Cost projections indicate that the system can be implemented for between 25 and 75 million dollars depending on the performance and configuration selected. If the potential that is currently projected for the MSBS could be realized through a continued aggressive research and development program, such a system could be implemented in the coming decade.

A more complete discussion of the points just covered was included in the document "Magnetic Suspension and Balance System (MSBS) - A Brief Technical and Programmatic Description" which was sent with the survey form to each of the survey participants. A copy of this document is shown in Appendix I.

2.2 SURVEY FORM

A form entitled "Magnetic Suspension and Balance System (MSBS) for Wind Tunnel Testing - Survey of Technical Needs" was formulated to meet the requirements of the present study. The form was subjected to thorough review by NASA, Air Force, and private industry personnel and was revised to reflect the review comments. The survey forms and MSBS descriptions were sent to nine companies involved in aerodynamic testing.

A copy of the survey form is included on the following pages. It consists of thirteen questions, some of which have several parts. The first four questions seek to determine the degree to which current and future wind tunnel test programs are influenced by support interference. The fifth through twelfth questions deal with such issues as appraisal of the MSBS in various testing roles, types, and categories of tests that would most benefit from the MSBS, potential benefit of the MSBS to future systems, priority of MSBS application, potential MSBS applications not previously discussed, reservations and concerns about the MSBS, and an indication of the respondent's level of support to the MSBS program.

2.3 INTERVIEWS

After receipt and review of the completed survey forms, a face-to-face interview was arranged with eight of the survey respondents. The purpose of the interviews was to obtain an in-depth understanding of the answers to the survey questions. Each organization was encouraged to have interested members of their staff present at the interview in addition to the primary respondent.

The interviews were generally begun by showing a videotape documenting the MSBS work at the University of Southampton. The videotape showed actual models of several types suspended in the University of Southampton facility. It clearly illustrated the high degree of model control now possible at angles of attack up to 60 degrees. The dynamic stability capabilities of a MSBS were also illustrated by a model in several types of oscillatory motion at several frequencies. The showing of this videotape was very useful in conveying the capabilities and potential of the MSBS and established a frame of reference for further discussion.

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?

____

____

2. Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?

Example: ____

____

____

Description of solution (i.e. repeat testing, modified hardware, etc.) ______________________

____

____

Impact on the test program was: critical ______, substantial ______, routine ______, minimal ______

3. What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?

____

____

4. What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?

No significant problems expected ____________; Moderate, but solvable problems expected ____________

Substantial problems expected ____

Comments: ____

____

____

____

____

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives						
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes						
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities						
TWO-BODY SEPARATION— general store separation, two-body staging						
DYNAMIC STABILITY TESTING						
OTHER (LIST)						

Of those listed above, I rate ______________________ *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit— Reduced Program Costs, Risks, etc.

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS			
TACTICAL FIGHTER AIRCRAFT			
AIR SUPERIORITY FIGHTERS			
GROUND SUPPORT AIRCRAFT			
MILITARY AIRLIFT/CARGO			
AIR-TO-AIR MISSILES			
AIR-TO-GROUND MISSILES			
GROUND-LAUNCHED MISSILES			
TACTICAL			
STRATEGIC			

(+) Substantial
(●) Needed
(−) Of little or no benefit

General Comments: ____

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available

General Comments: ____

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger $0 < M \lesssim 0.3$	Large Transonic 8 X 8 ft $0.2 < M < 1.3$	Midsized Transonic 4 X 4 ft (Approx.) $0.2 < M < 1.3$	Midsized Supersonic 4 X 4 ft (Approx.) $1.5 \leq M \lesssim 8$

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

____

____

____

____

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade		
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions		
Support Continued Basic R&D With Future Go Ahead Decision		
Cannot Support MSBS		

13. In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?

☐ *Yes* ☐ *No*

Comment: ______________________________

____

Response Prepared By: ______________________________

If Other Than Recipient: Telephone: ______________________________

Mailing Address:

____

____

____

SECTION 3.0
EVALUATION

The survey forms were sent to nine companies which conduct extensive wind tunnel testing. These companies were selected to represent a cross-section of the U.S. aeronautical industry by including both aircraft and missile manufacturers. The companies are listed below in their respective categories.

- Commercial Aircraft
  - Boeing Company
- Fighter Aircraft
  - General Dynamics - Fort Worth Division
  - Grumman Aerospace Corporation
  - Northrop Corporation - Aircraft Division
  - McDonnell Douglas Corporation - McDonnell Aircraft Company
- Bomber Aircraft
  - Rockwell International Corporation - North American Aircraft Operations
- Missiles
  - Hughes Aircraft Company - Missile System Group
  - Raytheon Company - Missile Systems Division
  - Martin Marietta Aerospace/Orlando - Missile Systems Division
  - Boeing Company

Completed survey forms were received from each organization with Boeing submitting two forms representing different areas within the company. Copies of the completed survey forms are included in Appendix II.

On-site interviews were conducted at eight of the companies. A list of attendees at each interview is included in Appendix III. A summary of survey form responses and discussions of these responses based on the interviews follow.

Question 1. On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?

Summary of Answers. Nine of the ten respondents experienced interference problems. Only two of the ten had empirical criteria to minimize the interference.

Discussion Based on Interviews. The survey respondents' problems with support interference depended on whether they were primarily aircraft or missile manufacturers. The aircraft group reported significantly more difficulty with support interference. Aft body simulation of fighter aircraft was cited as an area where support interference is severe. The lack of empirical support interference criteria generally was attributed to the extreme configuration dependence of the problem.

Question 2. Can you cite a program example(s) within your organization's past ten years of experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?

Examples of Test Programs Cited.

- Air Slew Missile - High Angle of Attack
- NASA/GAC Research Fighter Configuration - Sting Fouling
- EA-6B Ground Plane Test - Distorted Simulation
- C-2 Powered Model - Drag
- Advanced Design Configuration - Geometry Limitation
- B-1 Bomber - Afterbody/Exhaust Simulation
- YC-14
- ACLM (Air-Launch Cruise Missile)
- ACM (Advanced Cruise Missile)
- ESIP (Exhaust System Interaction Program)
- VTX Trainer - Sideslip Testing
- Copperhead Guided Projectile - Slot Flow Simulation
- Pershing II Missile
- F-16 Fighter - High-Angle-of-Attack Pitching Moment

Typical Solutions.

- Repeat testing (sting and strut supports)
- Model Modification
- Aerodynamic Fairing
- Model Support by Cable
- Several Sting Sizes
- Repeat Testing With and Without Seals
- Post-Test Analysis

Impact on the overall test program, reflecting difficulty in rectifying or accounting for support interference effects and potential significance to system performance were rated as:

- Critical - 1
- Substantial - 6
- Routine - 4
- Minimal - 0

Discussion Based on Interviews. The systems which experienced support interference represent a wide variety of configurations including fighter aircraft (F-16, NASA/GAC Research Fighter), bomber aircraft (B-1), transport aircraft (C-2, YC-14), air-to-ground missiles (ACLM, ACM), and ground-to-ground missiles (Pershing II, Copperhead). The steps taken to overcome the support interference problems were almost as varied as noted above. The most popular method seems to be testing with both sting and strut supports or with several size stings. The most severe problems were encountered during high angle-of-attack testing.

Question 3. What percentage of test program cost (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?

Average of Answers. Eight percent.

Discussion Based on Interviews. The percentage of test program cost devoted to solution of model support problems ranged from "minimal" to 40 percent depending on configuration and the method chosen by the particular organization to deal with the problem. The largest factor was reported for the Copperhead Guided Projectile which had slots in the aft end which created first-order support interference problems. This resulted in an extensive experimental and analytical program to resolve the problem. In some cases, manufacturers had to rely heavily on flight data to complete the definition of vehicle aerodynamics. This was particularly true of the missile manufacturers. It was not, however, regarded as a major hindrance to missile development.

Question 4. What degree of confidence do you place on conducting your organization's next-generation aircraft or missile development projects without encountering support interference problems?

Summary of Answers.

No Significant Problems - 2
Moderate, But Solvable, Problems - 5
Substantial Problems - 5

Discussion Based on Interviews. Once again, those predicting no significant support interference problems for next-generation vehicles were missile manufacturers. This is due at least in part to the reliance on flight test and to the robust control systems present on many missiles.

An area singled out as having substantial expected problems by aircraft manufacturers was separation of conformally carried stores from aircraft which are expected to be developed in the next few years. Conformal carriage negates the use of the sting support required in captive trajectory system (CTS) testing, thereby eliminating the most widely used experimental technique for obtaining separation characteristics of weapons from aircraft. The remaining experimental technique is dynamic freedrop testing which is more expensive and less accurate than the CTS technique due to the difficulty in matching the dynamic scaling laws at transonic speeds. The use of the MSBS offers the most attractive experimental approach to future aircraft weapon separation testing.

Question 5. Please provide your appraisal of the MSBS in the following roles.

Summary of Answers. The chart below summarizes the total number of responses received in each category.

Role	HIGHEST PRIORITY AREA	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives	2		2	6	2	1	
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes	4	1	4	3		1	2
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities	5	1	7		2	1	
TWO-BODY SEPARATION— general store separation, two-body staging	1		3	4	1		2
DYNAMIC STABILITY TESTING			3	6	1	1	
OTHER (LIST)	1		3				

Discussion of Responses Based on Interviews. High angle-of-attack testing had the largest number of responses as the highest priority area as well as the largest number in the "very important" category. One of the reasons for this is the difficulty in obtaining accurate static stability characteristics of fighter aircraft at high angles of attack. For example, the high angle-of-attack pitching moment of the F-16 was not correctly determined in wind tunnel testing due to support interference. Missile configurations are also susceptible to the same problem.

Second in overall priority rating was performance determination. The major concern was the trend to highly blended aircraft configurations which leave little or no room for sting supports. The accurate determination of propulsion effects on vehicle performance was also a factor in the priority rating of this category.

Static stability, two-body separation, and dynamic stability followed with an essentially even priority rating. Dynamic stability was an interesting area in the interview discussions. Several respondents indicated an interest in obtaining more dynamic stability data. On the other hand, no one seems to be willing to expend a significant effort to obtain such data even with a magnetic suspension balance system. It would appear that even crude estimates of dynamic stability coefficients are adequate for most systems to enter into flight test.

Question 6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit.

Summary of Answers. Types of Testing

- Aircraft
  - Store Separation
  - Final Performance Verification
  - Loads/Load Distribution
- Missiles
  - Zero-Lift Axial Force
  - Buffet Characteristics
  - Wake Characteristics
  - Jet Interaction
  - Heating Rate
- Both
  - High Angle of Attack
  - Static Stability
  - Propulsion/Inlet
  - Impulse/Transient
- Nature of Benefit
  - No Support Interference

- Quantitative Benefit
  - Greater Confidence in Data
  - Reduced Risk
  - Reduced Testing
  - Reduced Cost
  - Improved Data Accuracy

Discussion Based on Interviews. Many of the items listed are in areas previously identified as benefitting from the MSBS (Question 5). Several new items also appear including loads/load distribution, heating rate, impulse/transient, buffet, wake, jet interaction, and propulsion/inlet. Inclusion of these items indicates that some specialized tests not previously considered for the MSBS may be applicable.

Question 7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts.

Consensus of Responses.

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS	•	•	•
TACTICAL FIGHTER AIRCRAFT	•	+	+
AIR SUPERIORITY FIGHTERS	+	+	+
GROUND SUPPORT AIRCRAFT	•	•	-
MILITARY AIRLIFT/CARGO	•	•	-
AIR-TO-AIR MISSILES	•	+	•
AIR-TO-GROUND MISSILES	•	+	+
GROUND-LAUNCHED MISSILES			
TACTICAL	•	+	•
STRATEGIC	-	•	•

(+) Substantial
(•) Needed
(−) Of little or no benefit

Discussion Based on Interviews. Fighter aircraft appear to be the system for which the MSBS is perceived to be of the most benefit. This is most likely due to the high angle-of-attack support interference problem and the trend toward blended configurations as mentioned earlier. Air-to-ground cruise missiles follow in importance because of their similarity to aircraft. Air-to-air missiles and ground-launched tactical missiles follow. It is somewhat surprising that three categories of missiles are rated to have substantial MSBS benefit in light of lower enthusiasm of missile manufacturers toward the MSBS. Note, however, that in a question such as this, missile applications are being rated by aircraft manufacturers and vice versa.

Question 8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available.

Summary of Answers. Examples:

- Aircraft
  - Air Superiority Fighter
  - Long-Endurance Patrol Aircraft
  - Advanced Tactical Fighter
  - Hypersonic Airplane
- Missiles
  - Air-Breathing Air-to-Air Missiles
  - Bomber Defense Missile
  - Anti-Ballistic Missile
  - Conformal Shaped Missiles
  - Advanced Cruise Missiles
  - Advanced Air-to-Surface Missiles
  - Transatmospheric Vehicles
  - Small ICBM's
  - Submunitions
  - Ramjet Missiles

- Development Year
  - 1985 - 2000
- Nature of MSBS Benefit
  - More Accurate Data

Discussion Based on Interviews. The number and diversity of vehicles which may be developed in the next 20 to 30 years is large. A consensus among those interviewed was that the problems of support interference will tend to grow as these new-generation vehicles are developed. The expected trend toward more blended configurations with greater propulsion system integration and resulting decrease in support options was the primary reason for this response. A specific example of this trend is the expected use of two-dimensional high aspect-ratio exhaust nozzles with thrust vectoring capability for future fighters.

Question 9. If a single large-scale MSBS system was built, which of the following applications would you favor?

Summary of Answers.

1st Choice - Large Transonic Tunnel
2nd Choice - Mid-sized Transonic Tunnel
3rd Choice - Mid-sized Supersonic Tunnel
4th Choice - Large Low-speed Tunnel

Discussion Based on Interviews. The clear first choice for a speed range and size of tunnel for the first operational MSBS system was the large eight-by-eight-foot transonic tunnel. This was followed by the mid-sized (four-by-four-foot) transonic tunnel. This result is consistent with the responses to Question 7 in which five of the nine ratings of substantial need for the MSBS were in the transonic speed range. The next choice was the mid-sized supersonic tunnel which is consistent with the three ratings of substantial need in Question 7. The large low-speed tunnel was clearly the last choice of the respondents for implementation of a MSBS, even though this application of the MSBS may be considerably simpler to solve technically.

Question 10. The following possible uses of the MSBS which come to mind based on my experience:

Answers not mentioned previously:

- Flutter Testing
- Damage Assessment, Failure Mode

Discussion Based on Interviews. This question was asked to draw responses which previously may not have been evident to proponents of the MSBS. Flutter testing was mentioned in the context of a question as whether the MSBS can provide the necessary frequency response for a good simulation of the rigid body degrees of freedom for flutter testing. This question deserves examination as a part of the MSBS research and development effort.

A type of test not mentioned on the survey form, but discussed in the interview with one of the respondents was aeroelastic testing. Specifically, is it possible to design a model whose wing deflection could be controlled by the MSBS? If this is possible, it would considerably simplify the present procedure of producing and testing different wings for simulating specific inflight "g" loadings.

Question 11. What reservations do you have concerning the MSBS, if any?

Summary of Answers:

- Facility cost, availability, performance
- Data accuracy
- Position and attitude measurement and control
- Dynamic stability techniques
- Simulation of propulsion effects
- Operation efficiency
- Model changes.
- Model design and cost
- Model visibility
- Model damage risk
- Effects of magnetism on instrumentation
- Adaptive wall capability

Control of multiple independent bodies
Telemetry through a magnetic field
Measurement of control surface aerodynamics

Discussion Based on Interviews. The respondents expressed several concerns with respect to a MSBS national facility. The primary concern was one of cost versus availability. If the facility occupancy is free, it would probably be fully occupied and impossible to obtain an entry at the desired time. If a full-cost recovery charge is made, then the testing will be too expensive to conduct except for limited entries designed to investigate specific support interference problems. These concerns can be better understood in light of the fact that many of the respondents had their own test facilities.

The next two concerns involve accuracy of data and model position. A related concern involves development of dynamic stability techniques. These concerns can be eliminated by demonstrations in a small-scale facility.

The next concern involves simulation of propulsion effects since the compressed gas simulation supplied through a sting support is not available. Flow through simulation can be provided if adequate space in the model is available. Other options might involve an on-board compressed gas supply or an on-board solid propellant gas generator. It was clear from the discussions that research in this area needs to be conducted so that a good propulsion simulation method is available for MSBS testing since propulsion effects are a primary reason for conducting MSBS tests.

The next category of concerns involves operational efficiency and model changes. While it appears that attitude changes for a specific configuration can be made very quickly with the MSBS, model changes which involve a facility shutdown may take longer. Specifically, will the magnets have to be shut down for personnel to enter the facility to make model changes? Another question involves how the model would be supported during MSBS startup and model changes. The respondents' feelings were that these questions should be thoroughly addressed before proceeding with a large-scale MSBS.

Concerns about the test models were also expressed. The respondents were concerned with model cost, risk of damage due to system failure, and visibility during testing. If it can be shown that conventional sting support models can be readily converted for MSBS testing by inserting the magnetic core in the balance cavity the cost concern will be alleviated. Work should be done to ensure that no single-point failure would lead to destruction of the model.

Another related group of concerns involved effects of magnetism on instrumentation and telemetry of measurements and control parameters through the magnetic field. Remotely driven control surfaces are often used on models to reduce on the number of tunnel shutdowns for model changes. In the MSBS environment the remote control surfaces will have to be operated through a telemetry system. In addition, such on-board instrumentation as pressure transducers and control surface balance will require that the measurements be telemetered out of the model. If this cannot be done effectively in an operational environment, the usefulness of the MSBS will be severely limited.

Two additional concerns were expressed. If multiple bodies are simultaneously released from an aircraft model, it is not clear how they could all be controlled by the MSBS. With the continuing development of the adaptive wall concept, can it be integrated with the MSBS.

Question 12 In summary, (check all that apply):

Favor and Support NASA's Goal to Implement MSBS in the coming decade	7
Endorse Moderate-Scale Technology Demonstration Experiments To Resolve Questions	10
Support Continued Basic R&D With Future Go-Ahead Decision	5
Cannot Support MSBS	

Discussion Based on Interviews. The overall level of support indicated both by the survey results and interviews is strongly but cautiously positive. As seen above, the largest response was to the item which concerned technology demonstration experiments. The second largest response was to the item supporting implementation of the MSBS within the coming decade. Support was also indicated for continued R&D with a future go-ahead decision. It is important to note that not one respondent indicated that they could not support some form of the MSBS program.

SECTION 4.0
SUMMARY

The respondents to the present survey could be classified into two basic groups--aircraft manufacturers or missile manufacturers. The aircraft manufacturers were generally more enthusiastic toward MSBS than the missile manufacturers, apparently because the support interference problems they have encountered have been more severe and of greater consequence to successful system performance. Both groups see a trend toward configurations that will have more significant support interference problems than today's configurations in the coming decades.

Endorsement of a MSBS development program was universal among the respondents. One respondent, Boeing, went so far as to write a letter of support for MSBS development (Appendix IV). However, most are concerned about cost-versus-availability issues if a national MSBS facility were to be constructed. Many of the respondents have in-house test facilities so they will be unwilling to commit large portions of a test program to a MSBS facility if the cost were high. On the other hand, if the cost to the user were very low, the facility would probably prove so popular that it would be difficult to get a test schedule. The role of the MSBS is generally perceived to be a facility where short test entries are made using existing models to investigate particular support interference problems or to conduct specialized test which are not possible in conventional facilities.

The potential MSBS users have a number of concerns with the operational aspects of testing in an MSBS facility. These include measurement techniques, model design, and other details that must be considered in a test program geared to generating information needed in a vehicle development program. These concerns can best be answered by an aggressive NASA program to further develop and prove the MSBS in all applicable areas of wind tunnel testing. The respondents are clearly interested in a "production-oriented" MSBS facility which would be capable of routine testing of many varieties and not with a "research-facility" capable of only limited types of testing.

SECTION 5.0
RECOMMENDATIONS

The following recommendations are presented for consideration by NASA as a result of the present study:

1. The MSBS technology development and demonstration program should consider all possible MSBS applications and should deal with all the concerns expressed by potential users. Consideration should be given to including work at a larger scale than is presently considered.

2. Conduct an annual or bi-annual MSBS symposium specifically designed to keep the industrial aeronautical community informed on MSBS development progress and to obtain their comments and suggestions.

3. Provide a position on the MSBS development team for a private industry wind tunnel test engineer from one of the interested companies. This person might be supported jointly by the engineer's company and NASA. The position could be rotated yearly among individuals from various companies. This would provide input of the industrial users' problems into the program at the working level.

4. Accept proposals from industrial concerns for conducting limited tests in the existing MSBS small-scale development facilities and in future development facilities. While the tests selected would necessarily be limited in scope and small in number, they could provide valuable input into the MSBS program as to the evolving needs of the aerodynamic test community with respect to MSBS needs.

5. Concentrate on promoting the MSBS not only from the viewpoint of more accurate data, but also from its contribution to new testing techniques--an example being the use of the MSBS in combination with the CTS for conformal carriage weapon separation.

SECTION 6.0
REFERENCES

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APPENDIX I

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) - A BRIEF TECHNICAL AND PROGRAMMATIC DESCRIPTION

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) - A BRIEF TECHNICAL AND PROGRAMMATIC DESCRIPTION

INTRODUCTION

A primary element of NASA's mission is to develop and operate advanced aerodynamic wind tunnel testing facilities in support of the US aerospace industry and to provide R&D and program support to US government agencies; i.e., NASA, DOD, DOE, and others. Currently NASA is involved, to varying degrees, in the four following thrusts to advance our national wind tunnel testing capabilities:

- provide full-scale subsonic testing capability using the new 80-by 120-foot wind tunnel nearing operational status at NASA Ames Research Center, Moffett Field, California
- provide a transonic testing capability at full-scale Reynolds numbers using the new cryogenic National Transonic Facility (NTF) which recently completed a series of checkout runs and will soon become operational at NASA Langley Research Center, Hampton, Virginia
- develop new wind tunnel test section wall designs that will eliminate or reduce wall interference on test models, i.e., the adaptive wall concept
- develop a practical magnetic suspension and balance system that will eliminate the need for mechanical model support systems (stings, struts, etc.) and the requirements for mechanical force and moment measuring systems

The historical development and impact of improvements in tunnel testing capabilities are shown in Figure 1. The significance of the need for national

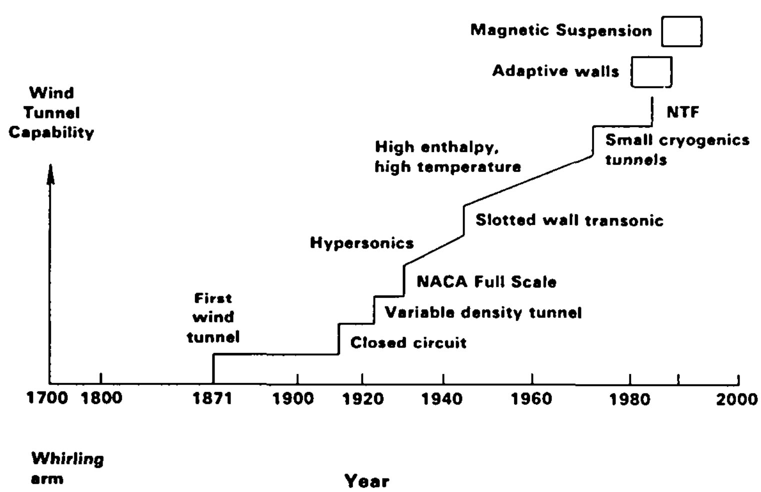


FIGURE 1. QUANTUM IMPROVEMENTS IN WIND TUNNELS

aeronautical programs to continually improve the US wind tunnel testing capability is illustrated by the data presented in Figures 2 and 3. Improved testing capabilities in terms of both reduced relative cost and enhanced data quality are factors which should enhance the United States position as the dominant supplier of aerospace equipment on the world market.

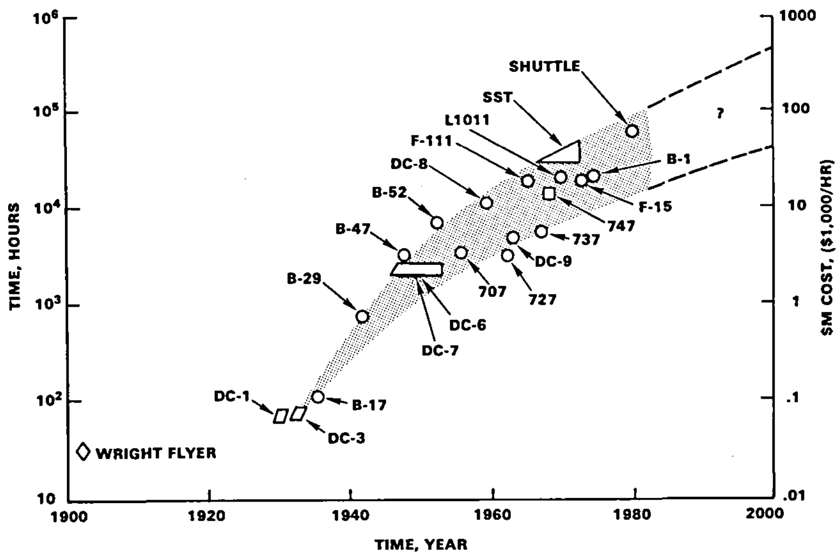


FIGURE 2. THERE IS A CONTINUED, SIGNIFICANT INCREASE IN THE USE OF THE WIND TUNNELS IN DEVELOPING INCREASINGLY MORE SOPHISTICATED, HIGHER PERFORMANCE AIRCRAFT

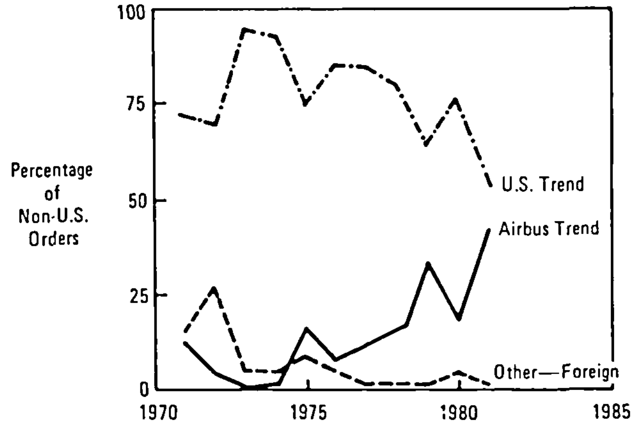


FIGURE 3 CIVIL TRANSPORT AIRCRAFT MARKET POSITION

This brief technical paper presents information related to one of the four major NASA wind tunnel improvement efforts: the development of a practical magnetic suspension and balance system for application to a large transonic wind tunnel.

MAGNETIC SUSPENSION - WHAT IT IS AND HOW IT WORKS

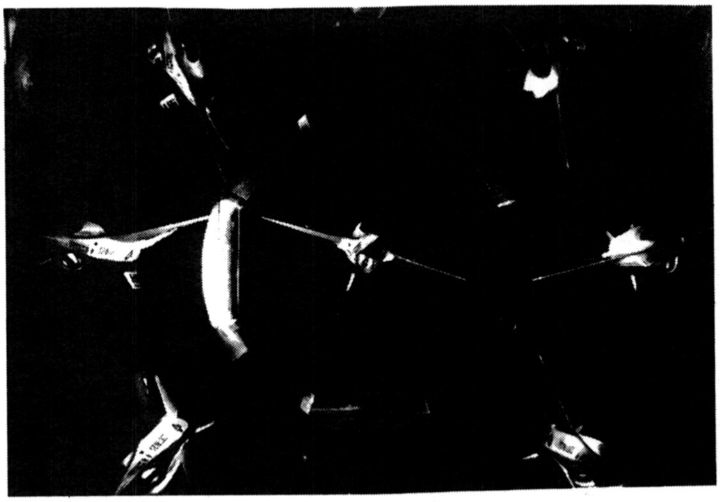
Magnetic suspension is a technique which has been used for over 25 years to support models and measure aerodynamic forces acting on the model in wind tunnel flows. The technique has been used in wind tunnels from very low subsonic speeds through the transonic speed regime and up to hypersonic speeds. The primary application to date has been to determine static stability coefficients, with emphasis on drag, of aircraft and missile configurations in the absence of sting or other disruptive model support effects in small scale test sections (up to 13 inches in diameter). A bibliography of relevant publications on the MSBS concept has been compiled by NASA and is included in this package.

The technique relies on the use of interacting magnetic fields and gradients in fields to produce forces and moments on the model. These forces:

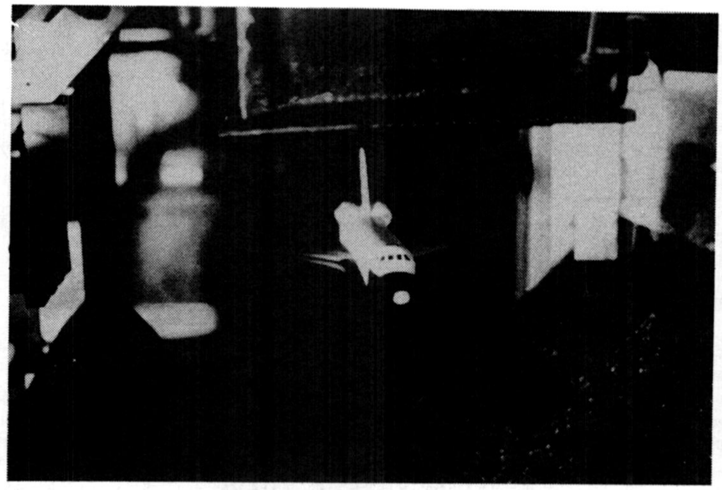
- suspend the model within the test section (counteract gravity)
- offset aerodynamic forces and moments acting on the model to maintain a stable testing attitude
- permit controlled movement of the model within the test envelope

Measurement of the currents in each of the supporting electromagnetic coils is one of the methods which can be used to accurately determine the aerodynamic forces and moments acting on the model.

Eleven magnetic suspension systems in the United States and Europe are known to have been successfully applied to aerodynamic wind tunnel testing involving forces and moments acting in up to six degrees of freedom, including roll. The more advanced of the present systems permit determination of static stability coefficients and selected dynamic stability derivatives on arbitrary lifting and nonlifting configurations as shown on the following page.



MIT



SOUTHAMPTON

CURRENT MSB SYSTEMS MEASURE FORCES IN SIX DEGREES OF FREEDOM ON ADVANCED WINGED CONFIGURATIONS

Forces and Torques

In the general application, a magnetic core of cylindrical shape is enclosed within the model fuselage. The core is energized to saturation by a magnetizing field ($\overline{M}$). Since like poles of magnetic fields repel and unlike poles attract, a strong rotating force or torque is applied to the magnetic core if it is placed within a separate applied field ($\overline{B}$). The magnitude of the torque is proportional to the product of the magnetizing and applied fields acting in the plane of the applied field. The only way the magnetized core can experience a net force in addition to the torque is if the applied field is nonuniform in the direction of the desired force. That is, a force in the y direction, F_Y, is achieved by the interaction of the magnetizing field, M, and the gradient of the applied field in the y direction (Covert, Reference 1). It is evident that full control in six degrees of freedom requires a number of separate magnet coils producing X, Y, and Z gradient fields for longitudinal and lateral forces and moments.

A Practical Application

Recent studies for NASA (Reference 2) show that a practical magnetic suspension and balance system can be developed for large transonic tunnels (2.5 x 2.5m test section) which:

- utilize magnet coils whose field strength, current, conductor size, and heat generation/dissipation are within current superconducting magnet technology

- produce forces and torques consistent with high lift, high maneuvering flight of winged vehicles even in high Reynolds number transonic flow
- permit precise measurement of aerodynamic forces and moments
- can be acquired for a capital expenditure of 25 to 75 million dollars

A proposed arrangement for ten separate magnet coils for this application is shown in Figure 4A, Reference 3. Four large coils produce gradient fields in the positive and negative Z (vertical) direction, four smaller coils produce gradients in the positive and negative Y (lateral) direction, and two large circumferential coils produce a pure axial gradient in the field and the axial component of force. The position and attitude of the model within the test volume is determined by a combination of electromagnetic and optical position sensors. An artists concept of the MSBS in a large transonic tunnel is shown in Figure 4B based on an overall system study by General Electric (Reference 2). These analytical studies reveal that forces and moments can be measured with comparable, or even improved, precision when compared to that possible using current strain gage balance technology.

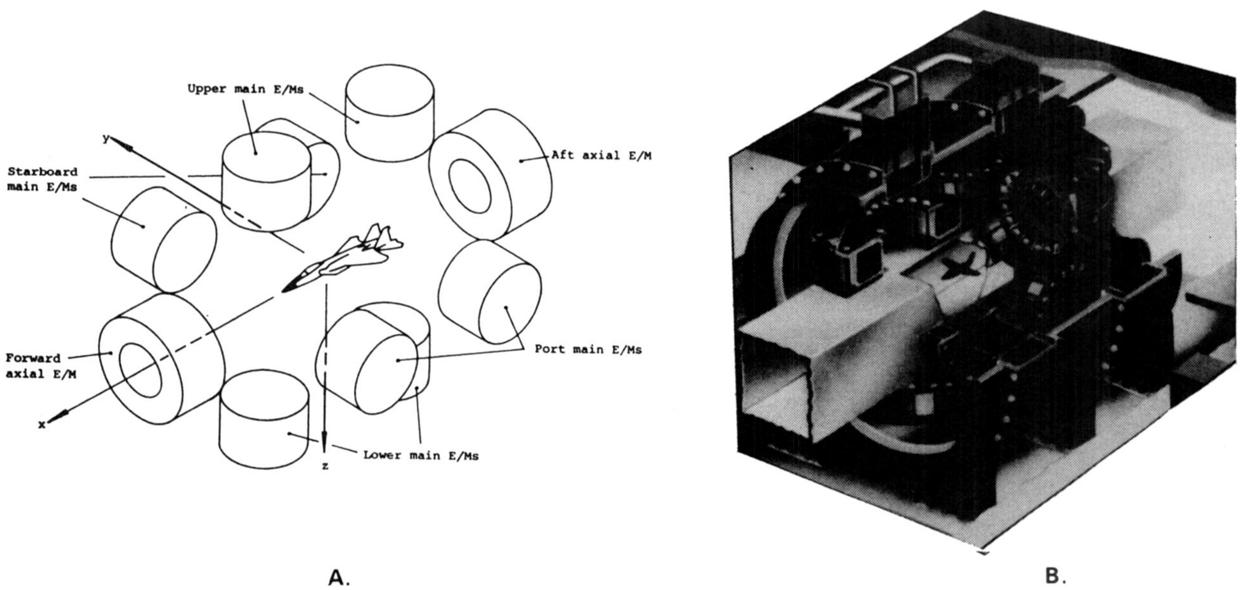


FIGURE 4. MSBS LAYOUT FOR 2.5 X 2.5m TRANSONIC WIND TUNNEL SHOWING STATE-OF-THE-ART MAGNETIC COIL TECHNOLOGY

Current Status and Future requirements

Ongoing pilot experiments (small scale) and analytical studies have shown:

- practical use of magnets to control model motion in six degrees of freedom
- precise position control and measurement of aerodynamic forces acting in all planes
- use of digital control techniques to enhance MSBS testing productivity
- the strong impact of superconducting magnet technology on practical large scale systems

A **number of factors remain to be demonstrated in moderate scale technology demonstration experiments** prior to proceeding to a very large scale application. These are:

- **accuracy of position sensing** consistent with three dimensional motion analysis
- **telemetry of on-board data** (multiple pressures) from the model
- **realizable accuracy in force** and moment measurements consistent with requirements for performance analysis of advanced aircraft
- **operational realiability** of the system and **overall productivity** of data

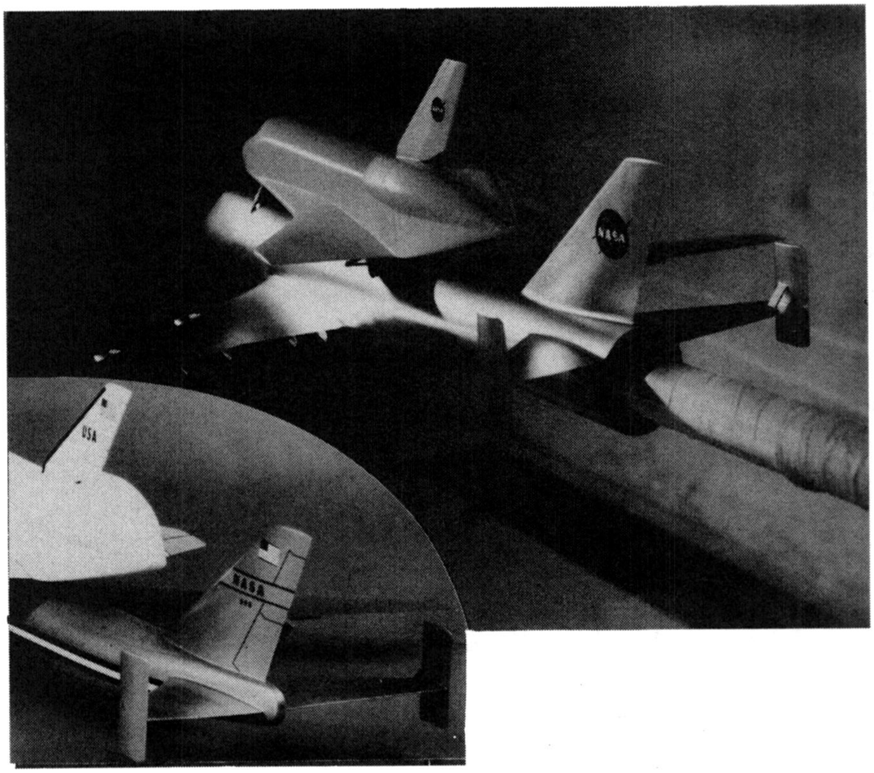
Favorable resolution of these technical questions is a prerequisite for a large scale MSBS effort.

PROVEN AND POSSIBLE APPLICATIONS

Successful testing of advanced aerodynamic configurations in current wind tunnels can only be accomplished if the data is corrected for recurrent support interference effects. The technical literature includes hundreds of examples of support interference effects and the difficulties experimenters encounter in deriving corrections on almost every new program. These effects compromise both static stability and performance determination.

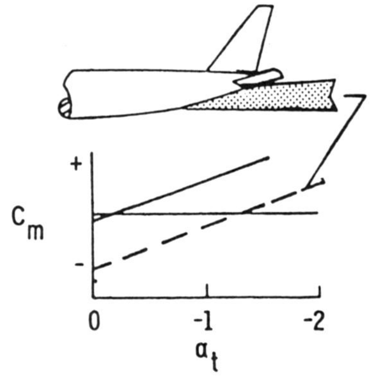
Support Interference Examples

Three examples of the alteration of test models to accommodate stings and their effects on aerodynamic characteristics are illustrated on the following page.

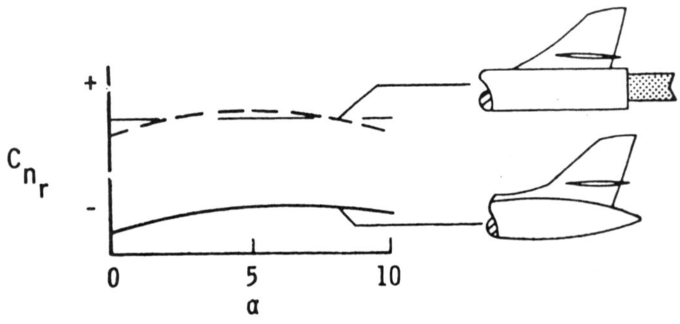


AFTERBODY ALTERATION OF THE COMBINED 747/SHUTTLE CONFIGURATION TO ACCOMMODATE A STING COMPATIBLE WITH THE HIGH COMBINED LONGITUDINAL AND LATERAL LOADS

Reference 4



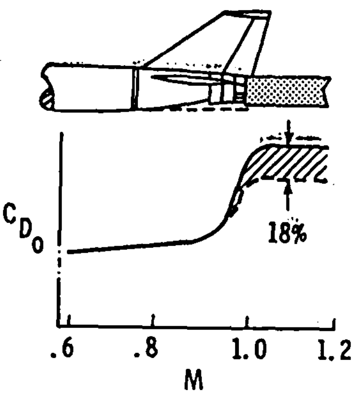
TRIM AND TAIL LOADS ON A SUBSONIC TRANSPORT DUE TO PRESENCE OF THE STING



YAW DAMPING ON A SUPERSONIC BOMBER INFLUENCED BY AFTERBODY DISTORTION TO ACCOMMODATE STING

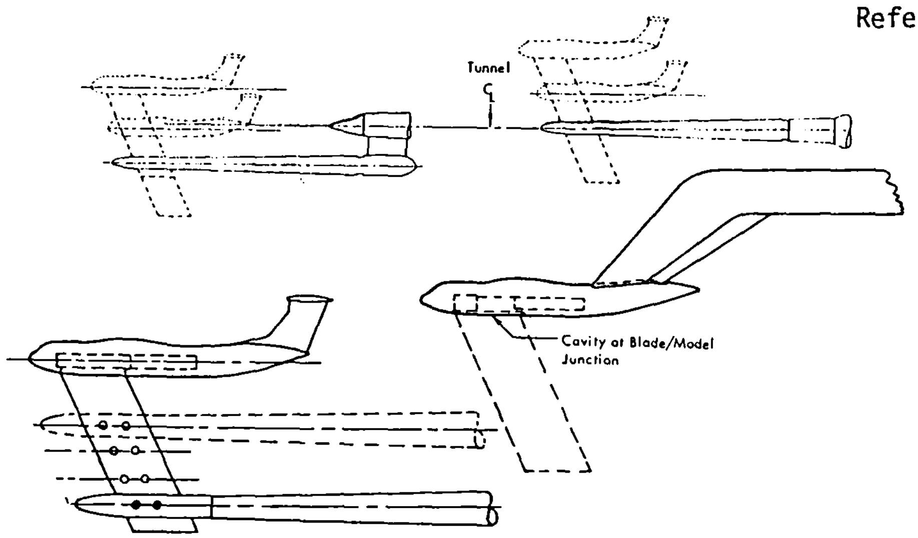
While criteria have been developed to minimize support effects on stability of many configurations, each configuration--and especially each new configuration--must be addressed separately in a rather empirical manner. In many cases, such as that shown for the 747/shuttle configuration, there is no solution that does not require compromise.

Two examples of support effects on critical determination of performance parameters such as range and payload are shown below.



AFTERBODY DRAG RISE ON A SUPERSONIC FIGHTER WAS SIGNIFICANTLY AFFECTED BY STING INTERACTION

Reference 5

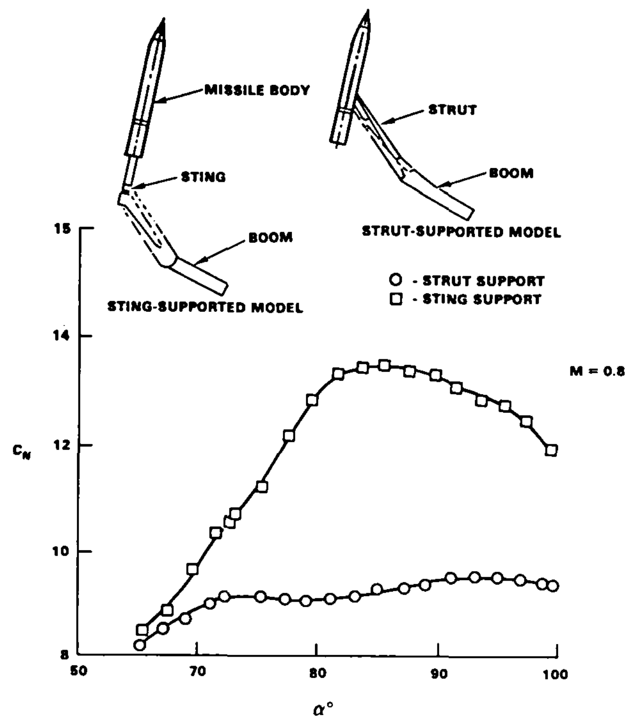


FINAL DETERMINATION OF CRUISE DRAG ON A MILITARY TRANSPORT REQUIRED THE USE OF MANY COMPLEX SUPPORT ARRANGEMENTS

A number of factors, other than support interference, such as engine exhaust plume, inlet air flow, Reynolds number (viscous effects), and airframe aeroelasticity must also be carefully evaluated to assess performance; however, this process could be simplified in the absence of support effects.

A recent example of critical support effects in the testing of maneuvering missiles at high angle of attack is shown below.

Reference 6



EFFECT OF MODEL SUPPORT ARRANGEMENT ON OGIVE CYLINDER NORMAL FORCE CHARACTERISTICS AT HIGH ANGLES OF ATTACK

Both the sting and the strut data are in error with no simple correction possible. The strut interferes with the wake closure in a highly Reynolds number sensitive manner and the sting alters the pressure distribution over the aft end of the missile body with a strong Mach number dependency. Normal force, pitching moment, and lateral stability data are affected. Similar wake closure, vortex shedding, and severe base flow distortion problems are encountered in testing of maneuvering fighter aircraft at very high angles of attack with conventional support systems as shown in Figure 5.

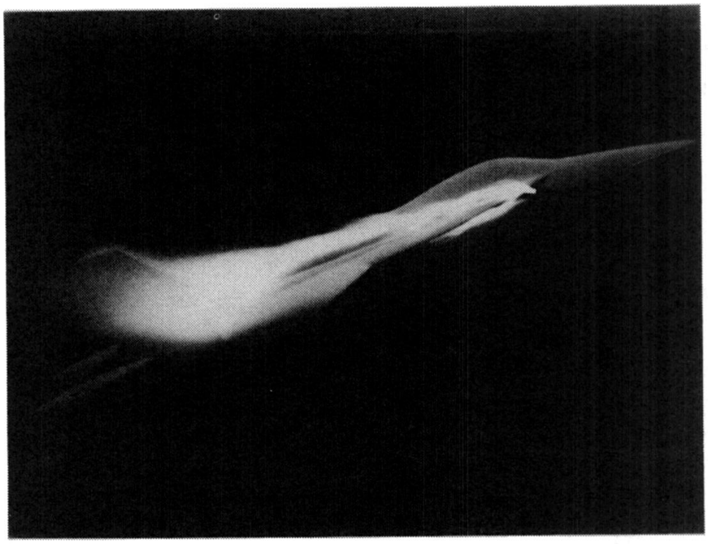


FIGURE 5. FIGHTER AIRCRAFT HIGH-ANGLE-OF-ATTACK MANEUVERING STABILITY — F-17 STRAKE VORTEX

MSBS Eliminates Support Interference

The classical support interference problems of:

- altered model geometry
- distorted airflow on the model
- distorted airflow behind the model

as illustrated in the previous examples, as well as several other support related constraints such as:

- limited static motion (X, Y, Z, and angle) with each physical setup which necessitates extra test hardware and repetitive testing
- limitations in achieving combined attitudes
- limited amplitudes and frequencies for dynamic stability testing without unacceptable sting oscillations

can be effectively eliminated with the magnetic suspension and balance system. Test program costs -- model, tunnel occupancy, data reduction -- remain to be evaluated relative to this enhanced testing capability.

Other Probable Applications of MSBS

Testing of multiple body separations (e.g., stores, crew escape modules, vehicle staging) could be easily accomplished with the MSBS without the numerous problems of multiple support systems--physical interactions and aerodynamic interference--which are routinely encountered using conventional techniques, such as the captive trajectory system (CTS), see Figure 6. The high-nose down pitch rate of the empty fuel tank on the F-16 during the ejection sequence could not be adequately simulated with the conventional captive trajectory support system or either the heavy or light scaling freedrop techniques. Similar problems were encountered in testing of the B-1 crew escape module ejection, see Figure 7 on the following page, at all flight conditions. Both problems were the result of interactions between the primary and secondary support systems. These and other store separation and two-body staging problems could be studied using the MSBS.

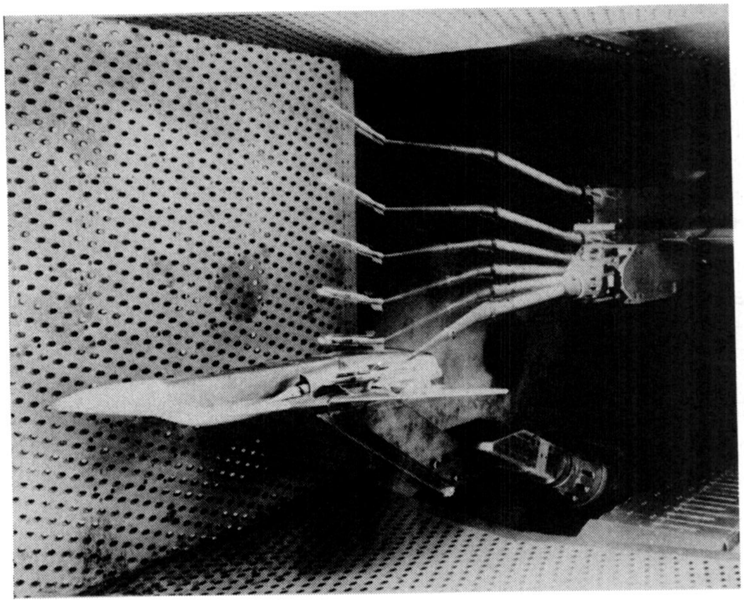


FIGURE 6. TYPICAL CTS TEST INSTALLATION

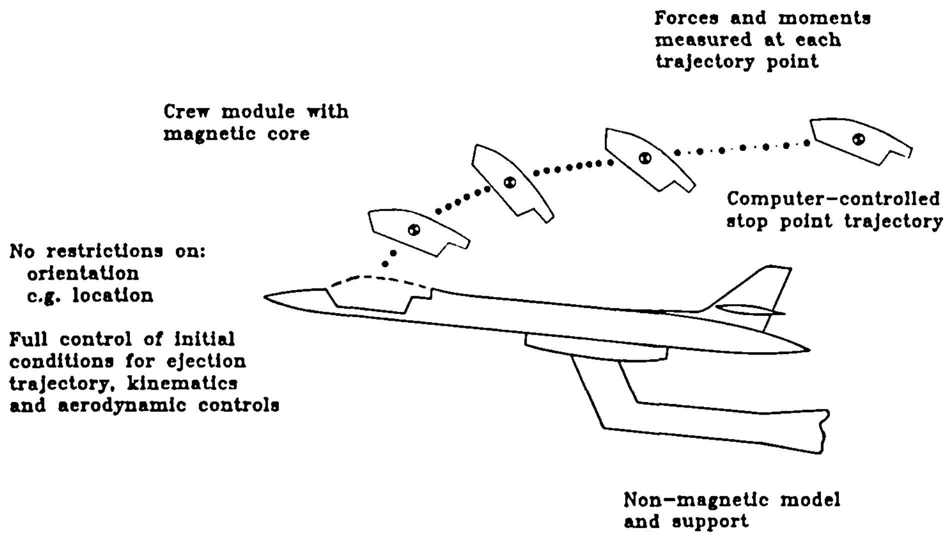


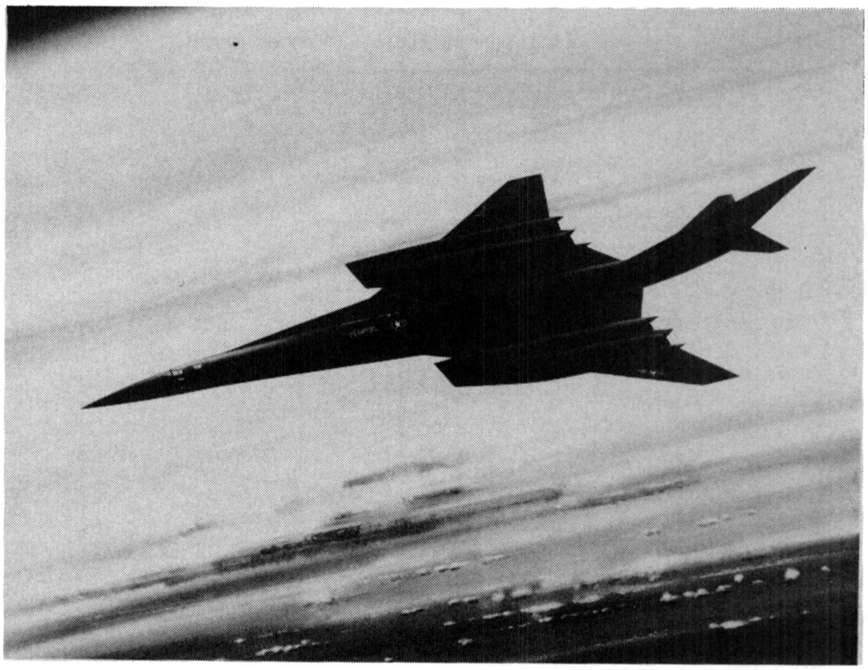
FIGURE 7. CREW ESCAPE MODULE

Experience shows that other less predictable benefits could arise if this important new testing technique becomes available such as:

- improved insight into high-angle-of-attack performance
- improved wind tunnel productivity through elimination of repetitive physical test setups, i.e., pressure, static stability, and dynamic stability testing could be accomplished with the same model and multiple setups would not be required to achieve high angle of attack or unusual attitudes
- simultaneous static and dynamic stability testing (without multiple models and test entries)
- reduction in data analysis and correction requirements

These factors might even offset added costs inherent in the use of the MSBS. In addition, it is likely that support interference effects will become more critical as:

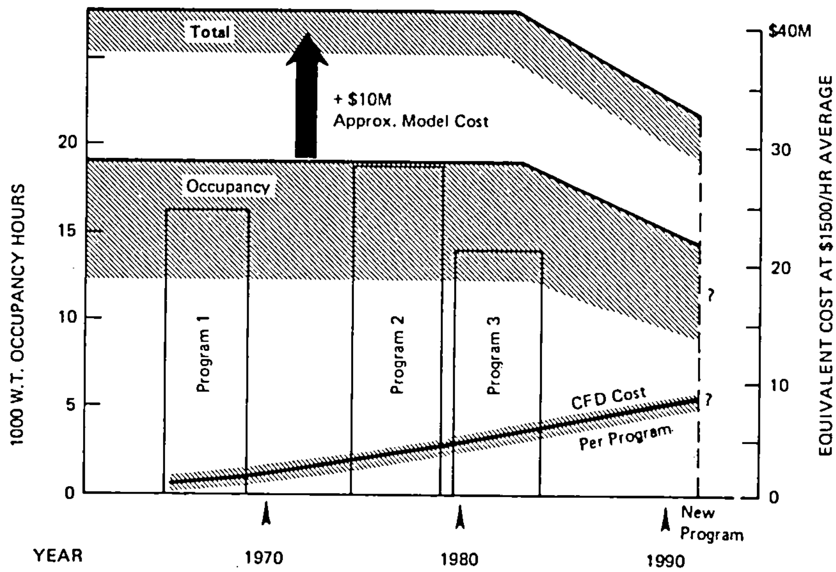
- Reynolds number is increased in newer transonic tunnels such as the NTF
- wall interference is decreased using advanced wall designs
- aircraft develop in sophistication (see photo on the following page)



NASA'S MSBS PLANS

NASA is presently conducting system development research with MSBS test units at Langley and the University of Southampton. A number of full scale system configuration studies have been completed to define magnet types and arrangements, control unit types and control philosophy, model position sensing systems, calibration techniques, and auxiliary equipment requirements. The most important of these system studies by General Electric (Reference 2) revealed no fundamental engineering limitations for a system compatible in size or in scale with large transonic tunnels similar to the NTF. Cost projections indicate that the system can be implemented for between $25 and $75 million, depending on the performance and configuration selected. If the potential that is currently projected for the MSBS could be realized through a continued aggressive R&D program, such a system could be implemented in the coming decade.

Wind tunnel test program and computational fluid dynamic costs associated with the successful development of major new aeronautical systems are large--currently projected to be over $30 million in equivalent 1981 dollars by 1990 for a typical commercial transport program as shown on the following page. These costs, coupled with the increasingly vigorous competition from foreign aircraft developers dictate that the United States maintain its testing excellence through improved experimental and computational facilities and techniques.



WIND TUNNEL AND CFD COSTS
TYPICAL COMMERCIAL TRANSPORT DEVELOPMENT PROGRAM
(1981 DOLLARS)

CONCLUDING REMARKS

Assuming continued favorable development of the MSBS, NASA is evaluating the need for further technology demonstration experiments and the feasibility of implementing a large-scale MSBS during the next decade. This independent survey by Sverdrup Technology is intended to obtain the response of industry and other important elements of the aeronautical community as to:

- needs for an MSBS in the 1990's
- the role of the MSBS in improving wind tunnel testing capabilities
- importance of the MSBS in supporting future wind tunnel test programs
- needs for continued R&D and technology demonstration experiments

Sverdrup Technology will provide an independent analysis of the survey responses to answer the question: does continued development with possible implementation of a MSBS in a large transonic tunnel in the 1990's appear at this time to be a justified investment of time and money by NASA?

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APPENDIX II

COMPLETED SURVEY FORMS

A. Boeing Aero. Labs

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING
— SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?

Transport models are not hindered due to evaluation techniques with alternate mounting systems. Aft body simulation on fighters is definitely hindered.

2. Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?

Example: YC-14 had a significant problem with seals around the upper swept strut mounting system.

Description of solution (i.e. repeat testing, modified hardware, etc.) Repeat testing with and without seals on models of two different sizes.

Impact on the test program was: critical _____, *substantial* X, *routine* _____, *minimal* _____

3. What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?

Transports: 2 to 5%

Fighters: 10%

4. What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?

No significant problems expected Transports; *Moderate, but solvable problems expected* _____;

Substantial problems expected Fighters

Comments: Experience base for support tare testing, and the existence of a very accurate external balance in the Boeing Transonic Tunnel, allow the use of several different techniques to accommodate different transport configurations.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

X - Transports
0 - Fighters

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives			0		X	
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes		0			X	
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities		0			X	
TWO-BODY SEPARATION— general store separation, two-body staging		0				X
DYNAMIC STABILITY TESTING			0		X	
OTHER (LIST)						

Of those listed above, I rate Perf. Determination *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
Fighter performance	+	
Stores separation from Fighters and Bombers	+	
Fighter stability at extreme angles of attack	+	
Support tare determination for transports	•	

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS		●	
TACTICAL FIGHTER AIRCRAFT	●	+	+
AIR SUPERIORITY FIGHTERS	●	+	+
GROUND SUPPORT AIRCRAFT			
MILITARY AIRLIFT/CARGO		●	
AIR-TO-AIR MISSILES			
AIR-TO-GROUND MISSILES			
GROUND-LAUNCHED MISSILES			
TACTICAL			
STRATEGIC			

(+) Substantial
(●) Needed
(–) Of little or no benefit

General Comments: The benefits of MSBS to performance prediction risks for transports will depend on the accuracy and repeatability of the data.

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Advanced technology fighters	5 yrs.	-Reduced risk of Perf. Prediction	
Conformal stores	5 yrs.		
Long endurance patrol aircraft	5-10 yrs.		

General Comments: Risks will be reduced only if wind tunnel data quality is as good as the best available today and if all other corrections, i.e., wall effects, Reynolds number, etc., are accurately known.

9. *If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)*

Large Low Speed 20 X 20 ft or Larger 0< M≤0.3	Large Transonic 8 X 8 ft 0.2 < M< 1.3	Midsized Transonic 4 X 4 ft (Approx.) 0.2< M< 1.3	Midsized Supersonic 4 X 4 ft (Approx.) 1.5≤ M≤ 8
(3)	(1)	(2)	(4)

10. *The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):*

11. *What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)*

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
Force data accuracy & repeatability	Yes		
Positioning accuracy (especially oc)	Yes		
Test costs	Yes		
Model visibility (for flow visualization)	Yes		

12. *In summary, I (check all that apply):*

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade	✓	Existing cryogenic tunnel development & wall correction/assessment programs should not suffer to attain this goal.
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	✓	Operational costs for testing with such a system must be fully understood before go ahead with a large scale system.
Support Continued Basic R&D With Future Go Ahead Decision		
Cannot Support MSBS		

13. *In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?*

XX *Yes* ☐ *No*

Comment: ______________________________

Response Prepared By: Ronald L. Bengelink, Supervisor Testing Development

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Seattle, Washington 98124

B. Boeing Wind Tunnel Test and Design

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING
— SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?

Yes.

2. Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?

Example: ALCM (Air-Launched Cruise Missile), ACM (Advanced Cruise Missile), ESIP (Exhaust System Interaction Program).

Description of solution (i.e. repeat testing, modified hardware, etc.) On ALCM, tests were made with two types of mount systems and modified configuration hardware, i.e. sting and strut mounts and inlet cover fairings.

Impact on the test program was: critical X *, substantial* ___ *, routine* ___ *, minimal* ___

3. What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?

15%

4. What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?

No significant problems expected ___ *; Moderate, but solvable problems expected* X *.*

Substantial problems expected X

Comments: We encounter support interference problems on all of our tests, some greater than others. Two problems in particular are severe: mounting of a typical modern missile with an aft-mounted inlet with multiple tail surfaces, and two-body separation tests.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives		X				
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes		X				
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities		X				
TWO-BODY SEPARATION— general store separation, two-body staging		X				
DYNAMIC STABILITY TESTING				X		
OTHER (LIST) inlet/propulsion		X				

Of those listed above, I rate performance *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit— Reduced Program Costs, Risks, etc.
Static stability	+	More accurate
Performance	+	Believable data.
High angle of attack	+	Less risk for
Two-body separation	+	program test
Propulsion/inlet	+	costs high
Heating rate	+	(all types)
Loads/load distribution	.	
Impulse/transient	.	

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS	-	-	-
TACTICAL FIGHTER AIRCRAFT	-	•	•
AIR SUPERIORITY FIGHTERS	-	•	•
GROUND SUPPORT AIRCRAFT	-	•	•
MILITARY AIRLIFT/CARGO	-	-	-
AIR-TO-AIR MISSILES	-	+	+
AIR-TO-GROUND MISSILES	-	+	+
GROUND-LAUNCHED MISSILES			
TACTICAL	-	+	•
STRATEGIC	-	•	•

(+) Substantial
(•) Needed
(–) Of little or no benefit

General Comments: Modern air-breathing missiles are the most in need of MSBS. Needed, too, for proper shock impingement data.

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Advanced Cruise Missiles	5	+	. More accurate test data . Validation of prediction methods . Less program risk . Less program cost . High test costs (all types)
Advanced Air-to-Surface Missiles	10	+	
Transatmospheric vehicles	·10	+	
High Endo Atmospheric Defense Missiles	15	•	
Small Intercontinental Ballistic Missiles	5	•	
Hypersonic Airplanes	15	+	

General Comments: With accurate, believable ground test data, program costs can be cut by large factors by reason of elimination of much redesign.

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger $0 < M \leq 0.3$	Large Transonic 8 X 8 ft $0.2 < M < 1.3$	Midsized Transonic 4 X 4 ft (Approx.) $0.2 < M < 1.3$	Midsized Supersonic 4 X 4 ft (Approx.) $1.5 \leq M \leq 8$
4	1	2	3

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

Load distribution tests

Impulse/transient/acceleration-compensated tests

Damage assessment, failure mode

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
Costs	Yes		
Set-up time.	"		
Model complications	"		
Maintenance of MSBS	"		
Risk-model damage	"		
Adaptive walls interaction	"		

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade	X	Needed to help our country help save free world
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	X	"
Support Continued Basic R&D With Future Go Ahead Decision	X	"
Cannot Support MSBS		

13. *In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?*

☒ *Yes* ☐ *No* *Comment:* ______________________

Response Prepared By: John A. Marsh / [illegible] 8/10/[illegible] 2-56-16

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C. General Dynamics/Fort Worth

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?

Problems are configuration dependent but always hinder simulation to some extent. Empirical criteria have been developed for reducing these effects at low angle of attack(e.g.minimizing sting flare angles to reduce buoyancy,etc.) Correction methods have also been developed but support interference still causes problems, particularly at high angle-of-attack.

2. Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?

Example: F-16 high angle-of-attack pitching moment characteristics were not determined correctly in the wind tunnel primarily due to support system interference. Large aft-fuselage sting modifications on some advanced aircraft studies have required modest amounts of testing to determine corrections.

Description of solution (i.e. repeat testing, modified hardware, etc.) Repeat testing with multiple types of support systems has been conducted.

Impact on the test program was: critical ____, *substantial* ____, *routine* ✓, *minimal* ____

3. What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?

<<1%

4. What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?

No significant problems expected ____; *Moderate, but solvable problems expected* ✓;

Substantial problems expected Dependent on configuration

Comments: Support interference at high angle-of-attack will continue to be a problem. Also, highly blended aero/propulsion configurations being considered for advanced concepts will require special attention to support interference when power effects are simulated.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives			✓			
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes			✓			
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities		✓				
TWO-BODY SEPARATION— general store separation, two-body staging				✓		
DYNAMIC STABILITY TESTING			✓			
OTHER (LIST)						

Of those listed above, I rate High Angle of Attack *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
Force Models Pressure (Loads) Models	Improved agreement with flight test data. Better prediction capability.	Reduced risks
Zero-lift pitching moment (C_{M_0})	C_{M_0} for trim measured directly	Eliminate cost of developing C_{M_0} estimates
High Angle of Attack	Support Interference eliminated	Reduced scope of flight test program

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS	•	•	•
TACTICAL FIGHTER AIRCRAFT	•	+	•
AIR SUPERIORITY FIGHTERS	+	+	•
GROUND SUPPORT AIRCRAFT	•	•	—
MILITARY AIRLIFT/CARGO	•	—	—
AIR-TO-AIR MISSILES	•	•	—
AIR-TO-GROUND MISSILES	•	•	—
GROUND-LAUNCHED MISSILES TACTICAL STRATEGIC	—	—	—

(+) Substantial
(•) Needed
(—) Of little or no benefit

General Comments: Difficult to generalize because of configuration dependence in each category. With the trend toward highly integrated aero/propulsion systems there is a need to simulate power effects. Applicability of MSBS for these cases is not readily apparent.

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available

General Comments:

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger $0 < M \leq 0.3$	Large Transonic 8 X 8 ft $0.2 < M < 1.3$	Midsized Transonic 4 X 4 ft (Approx.) $0.2 < M < 1.3$	Midsized Supersonic 4 X 4 ft (Approx.) $1.5 \leq M \leq 8$
3RD	1ST		2ND

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

____

____

____

____

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
o Measurement accuracy - (forces, moments, model attitude)	✓		✓
o Positioning accuracy for stores relative to A/C in separation testing	✓		✓
o Cost to using programs			✓

12. In summary, I (check all that apply):

	✓	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade		
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	✓	
Support Continued Basic R&D With Future Go Ahead Decision		
Cannot Support MSBS		

13. In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?

☒ *Yes* ☐ *No*

Comment: ______________________________

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D. Grumman Aerospace

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?

In some cases empirical methods have been developed which substantially reduce these effects. In other cases we are limited to investigations of incremental effects.

2. Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?

Example: NASA - GAC Co-op Program on Research Fighter Configuration - fouling
EA-6B Ground Plane Testing - distorted simulation
C-2 Powered Model Testing - rear leg drag

Description of solution (i.e. repeat testing, modified hardware, etc.) see attachment 1 question 2.

Impact on the test program was: critical _____, substantial X *, routine _____, minimal _____*

3. What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?

About 10 - 25%

4. What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?

No significant problems expected ________; Moderate, but solvable problems expected X *;*

Substantial problems expected Aerodynamic - propulsion integration is expected to be important in future fighters. Minimizing support effects at high angle of attack - needs to be addressed.

COMMENTS: High aspect ratio nozzles with vectoring will minimize mounting options.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives			X			
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes		X				
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities		X				
TWO-BODY SEPARATION— general store separation, two-body staging		X				
DYNAMIC STABILITY TESTING		X				
OTHER (LIST)						

Of those listed above, I rate High Angle of Attack *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
Same as in (5) above		

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS		+	
TACTICAL FIGHTER AIRCRAFT			
AIR SUPERIORITY FIGHTERS	+		
GROUND SUPPORT AIRCRAFT			
MILITARY AIRLIFT/CARGO	+		
AIR-TO-AIR MISSILES			
AIR-TO-GROUND MISSILES			
GROUND-LAUNCHED MISSILES			
TACTICAL			
STRATEGIC			

(+) Substantial
(•) Needed
(−) Of little or no benefit

General Comments: ______________________________

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Air superiority fighter, high angle of attack	1995-2000	Realistic data	

General Comments: ______________________________

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger 0< M≤0.3	Large Transonic 8 X 8 ft 0.2 < M< 1.3	Midsized Transonic 4 X 4 ft (Approx.) 0.2< M< 1.3	Midsized Supersonic 4 X 4 ft (Approx.) 1.5≤ M≤ 8
3	1	2	

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

Can MSBS provide the necessary frequency response for a good simulation of the rigid body degrees of freedom required for flutter testing?

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
Reservations are basically ones of operational feasability and model design; see enclosure 1, question 11.			

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade	X	
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	X	Emphasize operational aspects
Support Continued Basic R&D With Future Go Ahead Decision		
Cannot Support MSBS		

13. In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?

☒ *Yes* ☐ *No*

Comment: ______________________

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MSBS

Grumman Aerospace Corp.

ATTACHMENT 1

Question 2

NASA/GAC: frequent checking and repair of fouling circuit had to be done.

EA-6B: Had to cut out the downstream portion of the ground board and build an air tight box around the cut out in the underside. This prevented venting across the ground board in the vicinity of the horizontal tail. The box was filled with soft foam to simulate a smooth surface when the sting did not have to traverse into the box.

C-2 Powered Model: Two solutions were tried. First an aerodynamic fairing, around the rear leg, that moved up and down when the model was pitched. The second and preferred method, for pitch control for most of our tests, is a pair of thin cables, one attached near the nose the other near the aft portion of the fuselage.

Question 11

What is the relative size of the magnetic core to model fuselage volume for a flow through model? Is there room for instrumentation, telemetry automated controls? Our experience with fusion energy generation (TOKOMAK Project) has shown us that crystals and straingages are affected by varying magnetic fields. Can they be used in this magnetic environment? What do you use for operating power for these devices?

Is there a way to simulate propulsion exhaust effects other than flow through.

How do you prevent roll, especially at stall and above, to preclude inducing premature wing separation or wing rock? Is the MSBS a constraint on the time it takes to get the tunnel up to speed? How long does it take to change to a new α ? β ? flow conditions? How will these angles be measured?

For dynamic derivatives can uncoupled derivatives be obtained? How do you transfer dynamic stability data from model C.G. to aircraft C. G. or is there a requirement to put it in a certain location?

How much time and what is required to set up the model outside the tunnel? inside the tunnel? Can people make model changes in this magnetic field without injury or side effects? e.g. any thermal or vibration effects on teeth fillings, braces, eyeglasses, etc: or do you shutdown the magnetic field? How do you support the model during a model change? Are there limitations to the frequency of magnetic field shutdown during the day that can limit productivity?

E. Hughes Aircraft

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?

Support interference effects are always an important factor to be considered in determining model/facility/test plan objectives. We have experienced mechanical grounding problems of sting & model for high aspect ratio configuration, both under static & dynamic loadings.

2. Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?

Example: A significant effort is usually expended in the test plan/model design phase and during post test data reduction to correct for sting effects by analytic and empirical methods. We have included in the test plan on some programs obtaining

Description of solution (i.e. repeat testing, modified hardware, etc.) parametric data on the effects of sting size to aid in the sting correction analyses procedures. No real solution was achieved for the sting grounding problem.

Impact on the test program was: critical ____, substantial X, *routine* X, *minimal ____*

3. What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?

5 - 20% depending on the objectives/requirements of the program and availability of facilities

4. What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?

No significant problems expected ____; Moderate, but solvable problems expected X;

Substantial problems expected ____

Comments: Sting grounding during dynamic oscillations will continue to be a problem for high fineness ratio bodies at large angles of attack. The only practical solution without magnetic suspension is to minimize the effects by reducing the test load conditions at the cost of reduced accuracy.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives			X			
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes		X —	— X			
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities	X —	— X				
TWO-BODY SEPARATION— general store separation, two-body staging		X —	— X			
DYNAMIC STABILITY TESTING		X —	—	— X		
OTHER (LIST) Wake characteristics, jet interaction, buffet	X —	—	— X			

Of those listed above, I rate High α & Separation *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
All of the above	Elimination of sting effects	Better quality data characterization of the config. will reduce program risks. Cost impact is unknown (+ or -)

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS			
TACTICAL FIGHTER AIRCRAFT			
AIR SUPERIORITY FIGHTERS			
GROUND SUPPORT AIRCRAFT			
MILITARY AIRLIFT/CARGO			
AIR-TO-AIR MISSILES	-	+	+
AIR-TO-GROUND MISSILES	●	●	●
GROUND-LAUNCHED MISSILES			
TACTICAL	●	+	+
STRATEGIC	●	●	+

(+) Substantial
(●) ~~Needed~~ MODERATE
(−) Of little or no benefit

General Comments: ______

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Self Protect Weapon (Bomber Defense Missile)	90's	High α's:0-180°	
HEDS (Anti-ballistic missile)	90's	Jet interaction effects	
Arbitrary (conformal) shaped bodies	'90's-'00's	Sting elimination	

General Comments: ______

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger $0 < M \leq 0.3$	Large Transonic 8 X 8 ft $0.2 < M < 1.3$ (1)	Midsized Transonic 4 X 4 ft (Approx.) $0.2 < M < 1.3$ (2)	Midsized Supersonic 4 X 4 ft (Approx.) $1.5 \leq M \leq 8$ (2)

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

1. Buffeting characteristics - depends on stiffness characteristics of the suspension system
2. Jet interaction effects
3. Wake Studies

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
Facility costs and availability			X
Facility performance			X
Facility imposed requirements on the model			X

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade	X	
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	X	
Support Continued Basic R&D With Future Go Ahead Decision	X	
Cannot Support MSBS		

13. *In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?*

☒ *Yes* ☐ *No*

Comment: ____________________

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MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. *On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?*

In many cases, support interference has been a problem. We have no empirical criteria for interference minimization.

2. *Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?*

Example: Copperhead Guided Projectile; Air Slew; ASALM; Pershing II (2 Sting Test)

Description of solution (i.e. repeat testing, modified hardware, etc.) Modified hardware and repeat testing along with post test analysis.

Impact on the test program was: critical ____, *substantial* X, *routine* ____, *minimal* ____

3. *What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?*

Our estimates range from 15% on Air Slew to 30-40% on Copperhead and Pershing II. Therefore, we plan for 25% routinely.

4. *What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?*

No significant problems expected ____; *Moderate, but solvable problems expected* ____

Substantial problems expected X

Comments:

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives				X		
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes						X
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities		X				
TWO-BODY SEPARATION— general store separation, two-body staging			X			
DYNAMIC STABILITY TESTING		X				
OTHER (LIST) Motor/Aft Body Interface		X				

Of those listed above, I rate Other *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
Two-Body Separation	More extensive test matrix	Reduced risk
Static Stability	More accurate model & data.	Reduced cost and risk.
High Angle of Attack	Eliminates matching data from 2 stings	Reduced cost & risk.
Ramjet Inlet & Exhaust	Exit not blocked by sting	Reduced cost & risk.
Drag	Better base drag data.	Reduced risk.

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS			
TACTICAL FIGHTER AIRCRAFT			
AIR SUPERIORITY FIGHTERS			
GROUND SUPPORT AIRCRAFT			
MILITARY AIRLIFT/CARGO			
AIR-TO-AIR MISSILES	•	+	+
AIR-TO-GROUND MISSILES	•	+	•
GROUND-LAUNCHED MISSILES			
TACTICAL	-	+	•
STRATEGIC	-	+	•

(+) Substantial

(•) Needed

(—) Of little or no benefit

General Comments: ____________________

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Submunition Dispensing	90's	N Body Separation	Unknown
Ramjet Configurations		Flow Through	Unknown

General Comments: ____________________

9. *If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)*

Large Low Speed 20 X 20 ft or Larger 0< M≤0.3	Large Transonic 8 X 8 ft 0.2 < M< 1.3	Midsized Transonic 4 X 4 ft (Approx.) 0.2< M< 1.3	Midsized Supersonic 4 X 4 ft (Approx.) 1.5≤ M≤ 8
	(1)	(2)	(3)

10. *The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):*

____

____

____

____

11. *What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)*

	Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
1.	Control of Multiple Independent Bodies			X
2.	Telemetry of data through magnetic field			X
3.	Measurement of control surface aero	X		
4.	Secondard air supply (Rocket Plumes, RCS, JI, etc)	X		

12. *In summary, I (check all that apply):*

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade		
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	X	Limitations of current system do not warrant immediate full scale development
Support Continued Basic R&D With Future Go Ahead Decision		
Cannot Support MSBS		

13. In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?

☒ *Yes* ☐ *No*

Comment: __________

Response Prepared By: BOB R.E. Wittmeyer; Task Leader, Central Aero Group

If Other Than Recipient: Telephone: (305) 356-7069

Mailing Address:

Martin Marietta Aerospace

P.O. Box 5837; MP-323

Orlando, Florida 32855

G. McDonnell Aircraft

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. *On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?*

Because support interference problems are so configuration dependent, reliable empirical criteria do not, in general, exist.

2. *Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?*

Example: An advanced design configuration could not employ a conventional rear entry sting due to configuration complexities. Although the tests were exploratory, concentrating on low angles of attack only, about 10% of the test time was re-

~~*Description of situation (i.e. report number, program name, etc.)*~~ quired for definition of the support effects.

Impact on the test program was: critical ______, *substantial* __X__, *routine* ______, *minimal* ______

3. *What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?*

5-10% of model costs and test time. However, depending on the configuration and test condition requirements, this much may not adequately cope with the problem.

4. *What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?*

No significant problems expected __________; *Moderate, but solvable problems expected* __________.

Substantial problems expected __X__

Comments: No amount of test time or techniques can completely eliminate support interference effects for all conditions. The next generation of high performance aircraft may be more sensitive to the problem because of unusual design features. Further, some of the proposed future configurations may be less forgiving to aerodynamic uncertainties than those of today.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives		X				
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes	X					
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities		X				
TWO-BODY SEPARATION— general store separation, two-body staging			X			
DYNAMIC STABILITY TESTING		X				
OTHER (LIST)						

Of those listed above, I rate static stab/performance *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
Static force and moment and store separation	Elimination of support interference	Accuracy of results

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS		+	
TACTICAL FIGHTER AIRCRAFT	+	+	+
AIR SUPERIORITY FIGHTERS	+	+	+
GROUND SUPPORT AIRCRAFT	+	+	
MILITARY AIRLIFT/CARGO		+	
AIR-TO-AIR MISSILES			-
AIR-TO-GROUND MISSILES		+	+
GROUND-LAUNCHED MISSILES			
TACTICAL			
STRATEGIC			

(+) Substantial
(•) Needed
(−) Of little or no benefit

General Comments: ______________________________

____

____

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Vehicles with large amounts of static instability	Current	More accurate aerodynamics	
Unusual configurations not amenable to traditional support systems	Current		

General Comments: ______________________________

____

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

	1	2	3
Large Low Speed 20 X 20 ft or Larger $0 < M \leq 0.3$	Large Transonic 8 X 8 ft $0.2 < M < 1.3$	Midsized Transonic 4 X 4 ft (Approx.) $0.2 < M < 1.3$	Midsized Supersonic 4 X 4 ft (Approx.) $1.5 \leq M \leq 8$

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

____

____

____

____

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
Cost to model builder & user.			X
Accuracy of data.	X		

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade	X	
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	X	All activity should be accelerated with higher priority
Support Continued Basic R&D With Future Go Ahead Decision	X	
Cannot Support MSBS		

13. *In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?*

☒ *Yes* ☐ *No*

Comment: ______________________________

Response Prepared By: Jack M. Abercrombie

If Other Than Recipient: Telephone: (314) 232-3273

Mailing Address:

McDonnell Aircraft Company

Dept 341, Bldg 32, Room 278

P. O. Box 516

St. Louis, MO 63166

H. Northrop Aircraft

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. *On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?*

Yes - degree very dependent upon the airplane. Aircraft like F-20 have little problem, but trainers and advanced fighters are more of a problem.

2. *Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?*

Example: VTX Trainer required two mounting arrangements - a straight sting for sideslip testing and a "hockey-stick" sting for rudder effectiveness and longitudinal data. Attempts were made to evaluate the support effects.

Description of solution (i.e. repeat testing, modified hardware, etc.) Tested with both support systems. While mounted on "hockey-stick" sting determined the effect of the straight sting model configuration.

Impact on the test program was: critical ____, substantial ____, routine ✓, minimal ____

3. *What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?*

Five percent (5%)

4. *What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?*

No significant problems expected ____; Moderate, but solvable problems expected ✓;

Substantial problems expected ____

Comments: Next generation aircraft offer significant challenges for mounting. Fuselages do not provide the needed space for strain-gaged balances and the back end of models with two-dimensional high aspect ratio nozzles and/or exits highly integrated into the fuselage, do not offer any method of sting access without significant lines modification.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives			✓			
PERFORMANCE DETERMINATION— range payload, best cruise Mach number, dash speed, maneuver envelopes			✓			
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities				✓		
TWO-BODY SEPARATION— general store separation, two-body staging			✓			
DYNAMIC STABILITY TESTING			✓			
OTHER (LIST)						

Of those listed above, I rate static stability/ performance *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
Transonic stability and performance determination.	Stability and drag directly without correction for support.	Greater confidence, reduced risk, less testing.

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS			
TACTICAL FIGHTER AIRCRAFT	–	•	–
AIR SUPERIORITY FIGHTERS	–	•	–
GROUND SUPPORT AIRCRAFT	–	•	–
MILITARY AIRLIFT/CARGO			
AIR-TO-AIR MISSILES			
AIR-TO-GROUND MISSILES			
GROUND-LAUNCHED MISSILES			
TACTICAL			
STRATEGIC			

(+) Substantial
(•) Useful
(–) Of little or no benefit

General Comments: ______________________________

____

____

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Advanced Tactical Fighter	1988-90	Stability and performance unclouded by support effect.	

General Comments: ______________________________

____

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger $0 < M \leq 0.3$	Large Transonic 8 X 8 ft $0.2 < M < 1.3$	Midsized Transonic 4 X 4 ft (Approx.) $0.2 < M < 1.3$	Midsized Supersonic 4 X 4 ft (Approx.) $1.5 \leq M \leq 8$
3	1	2	

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
Need for interference-free data with correct inlet/exit flow.		√	
What happens to model and tunnel if you lose power or control?			√

Cost benefit?

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade	√	We favor continued development in a one-step-at-a-time fashion with evaluation, both of progress on the techniques, and of the projected need, at each step. While we feel that this is potentially a valuable capability, we would not want NASA to put so much effort and money into this that it impacts their more conventional wind tunnel facilities and technique development.
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	√	
Support Continued Basic R&D With Future Go Ahead Decision	√	
Cannot Support MSBS		

13. In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?

☑ *Yes* ☐ *No*

Comment: ______________________

Response Prepared By: Fred W. Peitzman, Acting Manager - Aerosciences Laboratory, Test

If Other Than Recipient: Telephone: (213) 970-4584

Mailing Address: Orgn. 3844/64
Northrop Aircraft
One Northrop Avenue
Hawthorne, CA 90250

I. Raytheon

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING — SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. *On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?*

Support interference problems have not hindered our simulations of missile aero-dynamic characteristics. We do not consider any empirical corrections necessary.

2. *Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?*

Example: None within past 10 years. Prior to that involved in Air Slew Missile Test program at AEDC (1972-73).

Description of solution (i.e. repeat testing, modified hardware, etc.) Repeat testing (sting and strut supports)

Impact on the test program was: critical ____, *substantial* X, *routine* ____, *minimal* ____

3. *What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?*

Negligible amount

4. *What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?*

No significant problems expected X ; *Moderate, but solvable problems expected* ____

Substantial problems expected ____

Comments: ____

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives				X		
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes						X
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities				X		
TWO-BODY SEPARATION— general store separation, two-body staging						X
DYNAMIC STABILITY TESTING			X			
OTHER (LIST)						

Of those listed above, I rate high angle of ... attack *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit— Reduced Program Costs, Risks, etc.
High angle of attack	Support removal	Reduced program costs, data accuracy.
Zero-lift axial force	"	Data accuracy.

7. From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS			
TACTICAL FIGHTER AIRCRAFT			
AIR SUPERIORITY FIGHTERS			
GROUND SUPPORT AIRCRAFT			
MILITARY AIRLIFT/CARGO			
AIR-TO-AIR MISSILES	+	+	+
AIR-TO-GROUND MISSILES	+	+	+
GROUND-LAUNCHED MISSILES			
TACTICAL	+	+	-
STRATEGIC			

(+) Substantial
(●) Needed
(–) Of little or no benefit

General Comments:

8. Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
Air breathing, air-to-air missiles.	1985	Support removal, drag estimation	Data accuracy

General Comments:

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger $0 < M \leq 0.3$ 3	Large Transonic 8 X 8 ft $0.2 < M < 1.3$	Midsized Transonic 4 X 4 ft (Approx.) $0.2 < M < 1.3$ 2	Midsized Supersonic 4 X 4 ft (Approx.) $1.5 \leq M \leq 8$ 1

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

____

____

____

____

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
Data accuracy compared to conventional testing.	X		X
Capability to control and measure α β ϕ δ	X		

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade		
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	X	
Support Continued Basic R&D With Future Go Ahead Decision	X	
Cannot Support MSBS		

13. *In evaluating responses to this questionnaire, the Sverdrup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?*

☒ *Yes* ☐ *No*

Comment: We would very much like to have additional information on MSBS and its capabilities, limitations etc.

Response Prepared By: Dana Morse

If Other Than Recipient: Telephone: (617) 274-7100 - X3221

Mailing Address:

Raytheon Company
Hartwell Rd.
Bedford, MA. 01730
Mail Stop M3-13

J. Rockwell International

MAGNETIC SUSPENSION AND BALANCE SYSTEM (MSBS) FOR WIND TUNNEL TESTING
— SURVEY OF TECHNICAL NEEDS —

The following four questions seek your judgement of the support interference problem as it presently exists

1. *On typical or routine aerodynamic test programs conducted by your organization, do support interference problems hinder simulation or have empirical criteria been developed to minimize interference?*

Support interference hinders simulation and additional testing is required to obtain support interference tares.

2. *Can you cite a program example(s) within your organization's past ten years experience in which a significant portion of the test program was used to correct (adjust) for adverse sting/support interference effects?*

Example: On the B-1 program a significant portion of the test program was dedicated to correcting for sting support interference effects and obtaining the correct afterbody data with engine exhaust simulated.

Description of solution (i.e. repeat testing, modified hardware, etc.) A strut mounted afterbody model was tested with the aircraft lines and also with a dummy sting to obtain corrections for the sting mount.

Impact on the test program was: critical ____, *substantial* ____, *routine* X, *minimal* ____

3. *What percentage of test program costs (engineering, test hardware, wind tunnel occupancy) do you estimate is routinely expended to cope with model support requirements or problems?*

About 5%. However, support tare testing would still be done on development models even if there were a national facility with MSBS.

4. *What degree of confidence do you place on conducting your organizations next generation aircraft or missile development projects without encountering support interference problems?*

No significant problems expected ____; *Moderate, but solvable problems expected* ____;

Substantial problems expected X

Comments: Shapes of next generation aircraft will be altered extensively to accommodate sting mounting; high angles of attack and yaw will cause support interference problems.

The following questions seek your technical judgement of benefits of the MSBS

5. Please provide your appraisal of the MSBS in the following roles.

Role	Essential To Program Success	Very Important	Improvement Over Current Technology	Useful Addition To Current Technology	Used Only For Check Points	No Application
STATIC STABILITY TESTING— determination of basic stability coefficients and derivatives			X			
PERFORMANCE DETERMINATION— range, payload, best cruise Mach number, dash speed, maneuver envelopes			X			
HIGH ANGLE OF ATTACK— basic stability, maneuver near stall, handling qualities		X				
TWO-BODY SEPARATION— general store separation, two-body staging			X			
DYNAMIC STABILITY TESTING			X			
OTHER (LIST)						

Of those listed above, I rate ____high α____ *as the highest in priority for application of MSBS.*

6. List the primary types of testing which your organization routinely performs for which you feel the MSBS will be of benefit (if none, so state).

Type of Testing	Nature of MSBS Benefit	Quantitative Benefit—Reduced Program Costs, Risks, etc.
Final performance verification testing after the configuration has been developed would be the prime benefit.	Improved simulation would increase confidence in the validity of the data.	Reduce risk
Store separation	Same as above	

7. *From the viewpoint of program success, assess the benefit of the MSBS for the following types of development efforts:*

	SUBSONIC	TRANSONIC	SUPERSONIC
CIVIL TRANSPORTS			
TACTICAL FIGHTER AIRCRAFT	o	o	o
AIR SUPERIORITY FIGHTERS	o	o	o
GROUND SUPPORT AIRCRAFT			
MILITARY AIRLIFT/CARGO			
AIR-TO-AIR MISSILES			
AIR-TO-GROUND MISSILES			
GROUND-LAUNCHED MISSILES			
TACTICAL			
STRATEGIC			

(+) Substantial
(•) Needed
(–) Of little or no benefit

General Comments: Any configuration in which the afterbody shape would have to be extensively altered to accept a sting mount would benefit from the MSBS.

8. *Cite specific examples of aeronautical systems, based on your evaluation of trends, which may be developed in the next two or three decades which could potentially benefit most from the MSBS, if available*

Example/Description	Approximate Year For Development	Nature of MSBS Benefit	Quantitative Evaluation of MSBS Effect, If Available
High maneuverable aircraft configurations		Reduction in high α data uncertainties	

General Comments:

9. If a single large-scale MSBS system was built, which of the following applications would you favor (Note 1st, 2nd, and 3rd choice)

Large Low Speed 20 X 20 ft or Larger 0< M≤0.3	Large Transonic 8 X 8 ft 0.2 < M< 1.3	Midsized Transonic 4 X 4 ft (Approx.) 0.2< M< 1.3	Midsized Supersonic 4 X 4 ft (Approx.) 1.5≤ M≤ 8
(3)	(1)	(2)	

10. The following are other possible uses of the MSBS which come to mind based on my experience (note order of importance):

A single facility equipped with an MSBS would provide the capability for additional testing that could be performed to increase confidence in performance predictions from wind tunnel data. However, it is not anticipated that it would reduce the overall wind tunnel program.

11. What reservations do you have concerning the MSBS, if any? (List reservation and evaluate)

Reservations/Concerns	Amenable To Further Engineering Development?	No Obvious Solution	I Need More Information
(1) Accuracy of force, moment, and attitude measurements	X		
(2) The added cost of a special model		X	

12. In summary, I (check all that apply):

	√	Comment
Favor and Support NASA's Goal to Implement MSBS in the coming decade	X	If required data accuracy can be demonstrated
Endorse Moderate Scale Technology Demonstration Experiments To Resolve Questions	X	Demonstration of data accuracy with MSBS needed before commitment of funds
Support Continued Basic R&D With Future Go Ahead Decision		
Cannot Support MSBS		

13. In evaluating responses to this questionnaire, the -drup Program Manager will visit selected individuals to further discuss responses. Will you be receptive to a visit, assuming that a mutually agreeable schedule can be arranged?

☒ *Yes* ☐ *No*

Comment: We will be pleased to meet with you.

Response Prepared By: Richard B. Russell

If Other Than Recipient: Telephone: (213) 647-3343

Mailing Address:

North American Aircraft Operations

Rockwell International Corporation

P.O. Box 92098

Los Angeles, CA 90009

Dept. 115, 011-BD02

APPENDIX III

INTERVIEW ATTENDEES

BOEING

September 28, 1984

Dick Day	Boeing
Fred May	Boeing
Bertil Dillner	Boeing
Bob Dixon	Boeing
Roger Hanson	Boeing
Larry Shrout	Boeing
Bob Doerzbacher	Boeing
John Marsh	Boeing
Fred Engman	Boeing
Alex Krynytzky	Boeing
Dick Butler	Sverdrup

GENERAL DYNAMICS/FORT WORTH

November 14, 1984

A. L. Madsen	General Dynamics
J. Schlichter	General Dynamics
C. Wilkerson	General Dynamics
W. R. Martindale	Sverdrup

GRUMMAN

December 18, 1984

Thomas Grunbeck	Grumman
Francine Gbondo	Grumman
Vincent Cimino	Grumman
Roy Charletta	Grumman
Dave Barry	Grumman
John McAfee	Grumman
Bob Jason	Grumman
Phil Manett	Grumman
William McAllister	Grumman
Jerry Levine	Grumman
Fred Shepheard	Grumman
Cap Catalanotto	Grumman
Bob White	Grumman
Stephan Malusa	Grumman
George Fenton	Grumman
Nick Federspiel	Grumman
Dick Kito	Grumman
Fritz Blomback	Grumman
Dick Butler	Sverdrup

HUGHES

September 25, 1984

Jim Kruse	Hughes
Ronald Reid	Hughes
Mas Amano	Hughes
Dennis Quan	Hughes
Kenneth Hayashida	Hughes
Telford Oswald	Hughes
Larry Wong	Hughes
Dick Butler	Sverdrup

MARTIN MARIETTA/ORLANDO

October 2, 1984

R. E. Wittneyer	Martin
J. W. Caplan	Martin
K. D. Salisbury	Martin
W. R. Martindale	Sverdrup

NORTHROP

September 24, 1984

Walter Rehm	Northrop
Dave McNally	Northrop
Merle Jager	Northrop
Rick Hughes	Northrop
Fred Peitzman	Northrop
Dick Butler	Sverdrup

RAYTHEON

December 17, 1984

Hugh Flomenhoft	Raytheon
Dana Morse	Raytheon
Ralph Bauer	Raytheon
James Coburn	Raytheon
Sidney Fagin	Raytheon
Juan Prieto	Raytheon
John Boudreau	Raytheon
Dick Butler	Sverdrup

ROCKWELL

September 24, 1984

R. B. Russell	Rockwell
Harvey Schellenger	Rockwell
Martin Crehan	Rockwell
Cary MacMiller	Rockwell
Clarence Mitchell	Rockwell
Bill Hartill	Rockwell
Steven White	Rockwell
G. D. Miller	Rockwell
Al Schoenheit	Rockwell
Dick Butler	Sverdrup

APPENDIX IV

LETTER OF SUPPORT FROM BOEING

BOEING COMMERCIAL AIRPLANE COMPANY

P.O. Box 3707
Seattle, Washington 98124

A Division of The Boeing Company

September 28, 1984
Aero-B8121-L84-835

Richard W. Butler
Sverdrup Technology, Inc.
Sverdrup Center
600 William Northern Boulevard
P. O. Box 884
Tullahoma, Tennessee 37388

Dear Dick,

We appreciate the time you took to personally brief us on the progress and plans for large scale Magnetic Suspension and Balance System development in the United States. We would like to supplement our previous response to your questionnaire with a strong statement in support of the development. We see a real need for this capability, especially for wind tunnel test problems such as; conformal stores separation, base flow and rocket plume effects, mounting system tares, and high angle of attack vortex flow breakdown.

We agree that this development is a national need and therefore properly within the scope of NASA's aeronautical research.

Sincerely,

BOEING AEROSPACE COMPANY

Roger L. Hanson
Chief of Aerodynamics

BOEING MILITARY AIRPLANE COMPANY

Bertil Dillner
Chief of Aerodynamics

1. Report No. NASA CR-3900	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle STUDY ON NEEDS FOR A MAGNETIC SUSPENSION SYSTEM OPERATING WITH A TRANSONIC WIND TUNNEL		5. Report Date May 1985 6. Performing Organization Code
7. Author(s) W. R. Martindale, R. W. Butler, and R. F. Starr		8. Performing Organization Report No.
9. Performing Organization Name and Address Sverdrup Technology, Inc. 600 William Northern Boulevard P.O. Box 884 Tullahoma, TN 37388		10. Work Unit No. 11. Contract or Grant No. NAS1-17423
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Contractor Report 14. Sponsoring Agency Code

15. Supplementary Notes

Langley Technical Monitor: Richmond P. Boyden
Final Report

16. Abstract

A survey of the U.S. aeronautical industry was conducted to determine if current and future transonic testing requirements are sufficient to justify continued development work on magnetic suspension and balance systems (MSBS) by NASA. The effort involved preparation of a brief technical description of magnetic suspension and balance systems, design of a survey form asking specific questions about the role of the MSBS in satisfying future testing requirements, selecting nine major aeronautics companies to which the description and survey forms were sent, and visiting the companies and discussing the survey to obtain greater insight to their response to the survey. Evaluation and documentation of the survey responses and recommendations which evolved from the study are presented.

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