The Ad Hoc Dynamic Test Working Group met at Marshall Space Flight Center, January 18 and 19. Members in attendance were: Robert S. Ryan, MSFC; Nathan Showers, MSFC; Tom Modlin, MSC; and S. A. Leadbetter, LRC. Guest attendees were: Larry Kiefling, Richard Schock, Jack Everett, and Jack Nichols, MSFC.

Jack Everett gave a presentation on a test program (viewgraphs attached) emphasizing the need for an integrated approach. The characteristics of this approach are:

1. There will be maximum integration of various test approaches, NASA facilities and analysis to provide minimum cost and minimum risk programs.

2. All major full-scale tests are to be conducted at MSC and MSFC.

3. The tests are to be coordinated with NASA, with contractor requirements compatible with test criteria.

4. Compatible data acquisition and data reduction techniques are to be used at each test facility.

5. Analysis techniques should be compatible with test approach.

6. This will require close working relations with analysis engineer and test engineer, with analysis leading test to serve as a basis for modal surveys.
The major problems foreseen are communications and a compatible set of boundary conditions for each analysis technique commensurate with the test set up. A very lively and informal discussion followed on the compatibility of various analysis and testing techniques, as well as how to establish appropriate boundary conditions.

The afternoon was spent planning the substructuring symposium to be held at MSFC in August or September in conjunction with a meeting of the Dynamics and Aeroelasticity Working Group Meeting. The purpose of this symposium will be to review state-of-the-art substructuring techniques as a means of evaluating their impact on dynamic testing approaches and technology. A letter is to be sent out to all contractors and individuals, known to be active in substructuring techniques, inviting submission of an abstract for possible inclusion in the symposium. It was agreed that authors should not give equation derivations, but concentrate on: What do authors think the limitations of the approach are? When do you think we should extend work? How would your technique be utilized in analyzing large complex structures such as the Shuttle? What is the technique? What type modes does it use? What type computer is used? Give results and comparisons to experimental data, if available. Abstracts are to be in by May 1, 1972.

Tom Hodlin outlined his thoughts on model testing. These are:

**Role of Model Testing**

- Preliminary design development testing parametric studies.
- Areas where analysis shows system insensitive; replace full-scale test with model.
- Model with limited full-scale verification.

Sy Leadbetter gave a rundown of his thoughts on model testing and some areas of concern in the overall test area. The outline of these thoughts follow:

1. Define problems in new situations in which previous knowledge cannot be extrapolated with confidence.
2. Obtain design information where theory is not adequate.
3. Check a theoretical method of design.
4. Time and money. Logistics of getting full-scale test early.
5. Develop test techniques.
6. Explain a failure or unexpected behavior.
Items of Concern in Test Area

1. Communications - close tie between user and tester.
2. How important is orthogonality in identifying proper modes?
3. How do we interpret test data - phase, plane, etc.?
4. Interface with other technology areas:
   a. aeroelasticity
   b. Pogo
   c. structure and materials
5. What are safeguards for test program to ensure that no unexpected data is missed?
6. What scale factor should be used (model test)?
7. Can test technology provide data compatible with analysis technology and program requirements?
8. How important is structural damping?
9. What is status of modal synthesis techniques?
10. Are thermal effects an important concern in testing?
11. Why test, and what to test for?
12. Compatibility of test data from various technology areas?

Example: Pogo, structure, propulsion.

A detailed discussion followed on these questions and what course of action should the committee now take, particularly since the shuttle configurations have drastically changed. Regardless of the configuration, three characteristics are present that impact testing:

1. Large temperature variations
2. Asymmetrical configuration
3. Point loads (mating structure)

Our basic question is, what blend of analysis and testing techniques best support the determination of vehicle dynamic characteristics. A pictorial view of the problem is shown on figure 1. To arrive at these answers, the following action items were assigned each member:

1. Review present technology plans (last meeting minutes) in light of present configurations and knowledge for missing links. Submit answer to chairman by February 11.

2. Determine pros and cons of different analysis and testing techniques. Submit to chairman by February 25.

3. Chairman is to send invitation to speakers for substructuring symposium. Letter attached.
Our next meeting will be a focused meeting with each member having an assigned area to discuss in order that we can start drafting criteria for determining the mix of analysis and test and additional technology that is needed. Meeting time will depend on timing of '74 funding requests.

Robert S. Ryan

Enclosure

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LRC/Mr. Robert C. Goetz, M. S. 340
LRC/Mr. Sumner A. Leadbetter, M. S. 230
LRC/Mr. David G. Stephens, M. S. 244
File (4)
What is the best way to support the load?
SHUTTLE INTEGRATED DYNAMIC TEST PROGRAM
PRESSURE FOE BOOSTER AND
C-40A ORBITER
SHUTTLE INTEGRATED DYNAMIC TEST PROGRAM
(PRESSURE FED BOOSTER AND 040A ORBITER)

TEST SPECIMEN: ORBITER FORWARD BODY

TESTS & OBJECTIVES:

ACOUSTICS:
- QUALIFY PRIMARY & SECONDARY STRUCTURES & BRACKETS
- VERIFY COMPONENT & SUBSYSTEM VIBRATION TEST SPECIFICATIONS
- DETERMINE ACOUSTIC LEVELS IN CREW COMPARTMENT FOR CREW COMFORT

MODAL SURVEY:
- DETERMINE MODAL CHARACTERISTICS OF ASSEMBLY FOR RIDE CHARACTERISTICS
- OBTAIN DATA FOR POGO & LOADS ANALYSES

LOCALIZED VIBRATION:
- DEFINE COMPONENT EFFECTIVE MODES
- FILL VOIDS THAT MAY OCCUR IN MATH MODELS AND/OR ACOUSTIC TEST SPECTRUM

HARDWARE REQUIRED:
- FORWARD BODY ASSEMBLY - WITH ALL SIGNIFICANT MASSES DYNAMICALLY SIMULATED ON FLIGHT BRACKETRY

POSSIBLE FACILITIES:
- MANNED SPACECRAFT CENTER
- LOCKHEED
- WYLE LABORATORIES
HARDWARE REQUIRED:
- COMPLETE ORBITER WITH MAJOR MASSES INSTALLED, INCLUDING PAYLOAD AND EXPENDABLE TANKS

TEST SPECIMEN: ORBITER ASSEMBLY WITH TANKS AND PAYLOAD

TESTS & OBJECTIVES:
- MODAL SURVEY:
  - OBTAIN ASSEMBLY & AFT STRUCTURE MODAL CHARACTERISTICS FOR USE IN UPDATING ORBITER MATH MODEL
  - PROVIDE ORBITER SYSTEM LEVEL POGO & LOADS ASSESSMENT
  - PROVIDE CONTROLS ASSESSMENT
  - PROVIDE DATA FOR FLUTTER ASSESSMENT

HARDWARE REQUIRED:
- COMPLETE ORBITER WITH MAJOR MASSES INSTALLED, INCLUDING PAYLOAD AND EXPENDABLE TANKS

POSSIBLE FACILITY:
- MARSHALL SPACE FLIGHT CENTER
SHUTTLE INTEGRATED DYNAMIC TEST PROGRAM (PRESSURE FED BOOSTER AND 040A ORBITER)

TEST SPECIMEN: COMPLETE MATED VEHICLE

TESTS & OBJECTIVES:

MODAL SURVEY:
- DETERMINE COUPLED VEHICLE FREQUENCIES
- DETERMINE MODE SHAPES
- DETERMINE STRUCTURAL TRANSFER FUNCTIONS
- DETERMINE STRUCTURAL/FLUID DAMPING
- FINAL POGO & LOADS ASSESSMENT ON SYSTEM LEVEL

HARWARE REQUIRED:
- COMPLETE LAUNCH VEHICLE AND PAYLOAD WITH MAJOR MASSES INSTALLED

POSSIBLE FACILITY:
- MARSHALL SPACE FLIGHT CENTER
DYNAMIC TEST HARDWARE FLOW

Component

FID. BODY ASSEMBLY

APR BODY ASSEMBLY

FIN ASSEMBLY

(PRESSURE-FED BOOSTER)

Booster Ass'y

Booster & Orbiter Ass'y

K3 = MODAL SURVEY TEST

K4 = VIBROACOUSTIC TEST (INCLUDES MODAL SURVEY)
INTRODUCTION

Space programs are usually conceived with well defined mission objectives but because of their inherent developmental nature, detailed plans require constant updating based on current developments. The transient nature of these evolving plans often causes an apparent lack of coordinated effort in certain technical areas due to limited visibility and arbitrary requirements at the inception of the program. With multiple contractors this can be a major problem when not only performance parameters but also technical approach are critical to the integrated system. An example of just such a problem is where contractors provide unique solutions to structural analysis and test requirements without knowledge or concern for subsequent applications of the analysis and supporting test data. The following discussion addresses potential problem areas associated with structural dynamics analysis and test for the Space Shuttle Program and suggests approaches for minimizing problems and reducing costs.
DISCUSSION

Vital to the success of the Shuttle dynamic test program is consistency in technical approach, which is more easily said than done. To achieve consistency, each contractor responsible for a subsystem must adhere to a rigid set of requirements for mass properties, static, and dynamic tests with the ultimate objective of providing coherent and compatible inputs to the integrated Shuttle System. However, the prime prerequisite for meeting this objective at program inception is the one most difficult to define, i.e., the detailed requirements for all aspects of the Shuttle Vehicle Dynamic Test Program.
B. Test Facilities

Define facility requirements and perform a facility survey to identify existing capabilities both within industry and government agencies. Make recommendations based on survey results for development of mutually compatible facility capabilities to fulfill test support requirements at all levels of assembly.

C. Data/Configuration Management System

Establish a central data/configuration management and retrieval system designed for the specific purpose of providing a current source of data to support Shuttle System dynamic analysis and test. As a minimum, the system should contain current mass properties, static, and modal data in a format consistent with both analysis and test criteria.

D. Data Reduction

Provide data reduction capabilities as part of the data management system to perform various types of data manipulation such as mass model coordinate transformations and connection of various related subsystems, coupling of subsystem static and dynamic models, modal uncoupling, mode plotting, load-deflection plots, computation of influence coefficients, orthogonality calculating, etc.
RECOMMENDATIONS

Define a plan for the ultimate analytical model and verification tests of the complete Shuttle System and establish mutually compatible plans for each successively lower level of assembly down to the component level. As a minimum, the plan should include the following for each level of assembly:

A. Criteria

- Mass Properties
- Math Modeling
- Test Methods
  - Static
  - Vibration
  - Acoustics
- Modal
- Documentation Requirements
- Configuration Management