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25. SPACE STATION STRUCTURAL PERFORMANCE EXPERIMENT

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Reg Berka (Paper #24) mentioned some of the Space Station disturbances that need to be dealt with. The Space Station can be used as a testbed for the determination of structural dynamics resulting from these disturbances. It will be one of the first very large space structures to be put into orbit that can't be tested totally on the ground. We need a means to hone our analytical methods by comparing actual results on orbit with those predictions that we've made analytically. The NASA/Langley Research Center has contracted us to define a flight experiment that could be used to measure Space Station dynamics during and after its assembly. By integrating sensors into the structure to measure its ambient dynamic responses, it will provide some information as to how it behaves during its evolution. The objectives of the experiment are to define a series of experiments to measure the dynamic responses due to disturbances to establish the experiment scenarios, and to identify the locations of the instrumentation that can be integrated into the structure. We have also defined the Space Station resources that are required so that they can be included in the Mission Requirements Data Base (MRDB). We used the 16-flight-assembly scenario that was recommended by Rockwell as the baseline. Figure 1 shows a cartoon of the structure that goes up on the first flight. It consists of one-half of the transverse boom including a pair of solar arrays and power radiator. Located on this drawing are the accelerometers, strain gauges, acoustic emission sensors, thermocouples, and a laser optical measurement system that can be used to measure the structural characteristics of that piece of structure. Accelerometers are placed at several locations along the beam so that its dynamic response can be measured and used to verify the preflight predictions. I will talk mostly about the accelerometers since that is the subject of the workshop. Low g accelerometers are envisioned for this structure. Because we don't plan

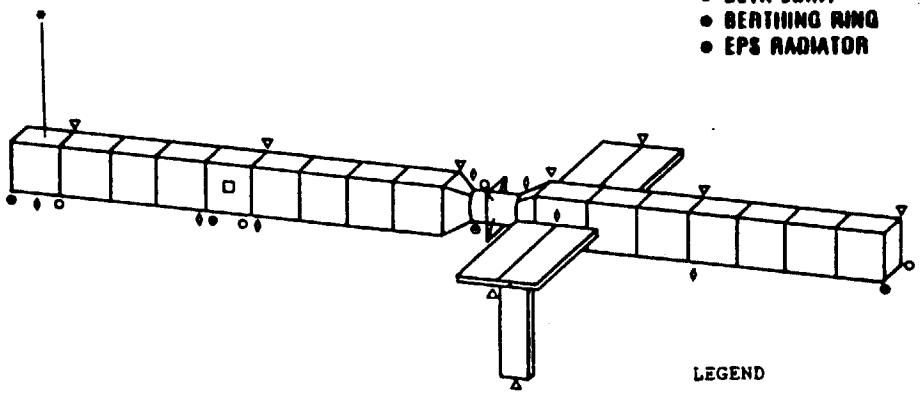
SPACE STATION

Work Package A - Technology Mission/ Experiment Definition

BOEING

FLIGHT 1

- PORT TRANSVERSE BOOM
- PORT SOLAR ARRAYS
- ACA MODULE
- ENERGY STORAGE MOD
- 4 BATTERIES
- ALPHA JOINT
- BETA JOINT
- BERTHING RING
- EPS RADIATOR



LEGEND

- △ Accelerometers
- ♦ Strain gauges
- ● Acoustic emission sensors
- ○ Thermocouples
- ✱ Laser optical system
- □ Remote data processors
- ■ Central data processor

FIGURE 1

to put up an excitation system on the structure to excite the structural dynamics, we will rely on the ambient excitation caused by control system forces and other disturbances. Accelerometers are located at the tip, between the tip and the alpha joints, and on each side of the alpha joint. There are other accelerometers located where the vertical keel will fasten into the structure, and close to the center of the transverse boom of the final configuration. At these locations we specified six linear accelerometers so that angular accelerations as well as linear accelerations can be measured. For instance, a triaxial accelerometer, a biaxial accelerometer, and a single-axis accelerometer can be used to measure the rotational accelerations along with the linear accelerations.

Figure 2 shows a mirror image of the transverse boom that would be attached on the other side. It is instrumented in a very similar fashion to the first half. I won't go through all of the 16 flights to show where the accelerometers are, but I will show enough so that you will see where the accelerometers are located for at least the major portion of the structure.

The upper keel boom is constructed on the third flight (Figure 3). The accelerometers are located at the junction with the transverse boom, half way up, at the corners, and in the middle of the upper keel.

On each of the major pieces of structure, we postulate the use of a remote data processor that would handle the data measured by the instrumentation on that portion of the structure. The remote data processors will have the capability of storing data, and of transferring them to a central data processor, which will be located in one of the modules.

During Flight 4 (Figure 4), the radiator and the instrumentation that is needed to measure its dynamics are added.

On Figure 5, the lower keel has been added. It is instrumented in a fashion similar to the upper keel. The module support structure is also added in this flight. It is also instrumented with accelerometers to measure its response before and after modules are attached.

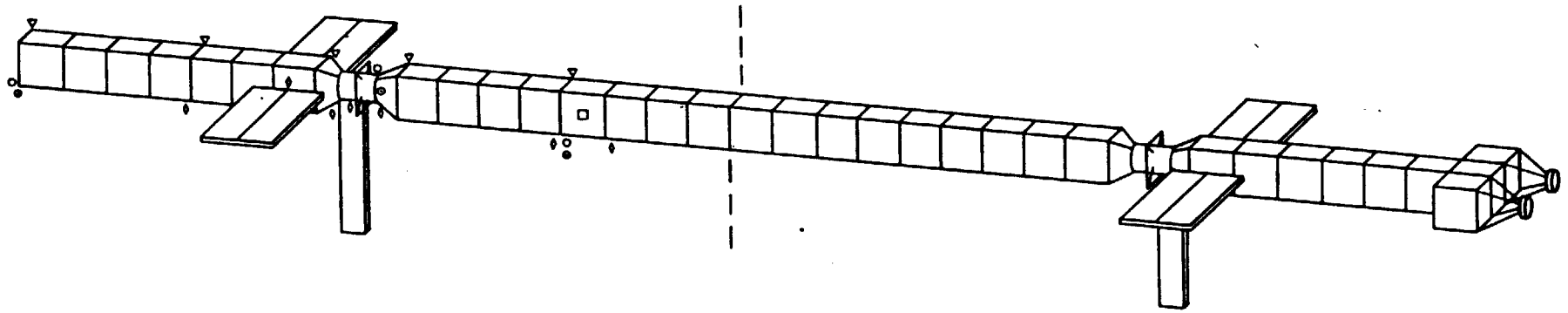
SPACE STATION

Work Package A - Technology Mission/ Experiment Definition

BOEING

FLIGHT 2

- STB TRANSVERSE BOOM
- STB SOLAR ARRAYS
- ENERGY STORAGE MOD
- 4 BATTERIES
- ALPHA JOINTS
- BETA JOINT
- 2 RCS MODULES
- EPS RADIATOR



LEGEND

- △ Accelerometers
- ◊ Strain gauges
- ● Acoustic emission sensors
- ○ Thermocouples
- ✱ Laser optical system
- □ Remote data processors
- ■ Central data processor

FIGURE 2

SPACE STATION

Work Package A - Technology Mission/ Experiment Definition

BOEING

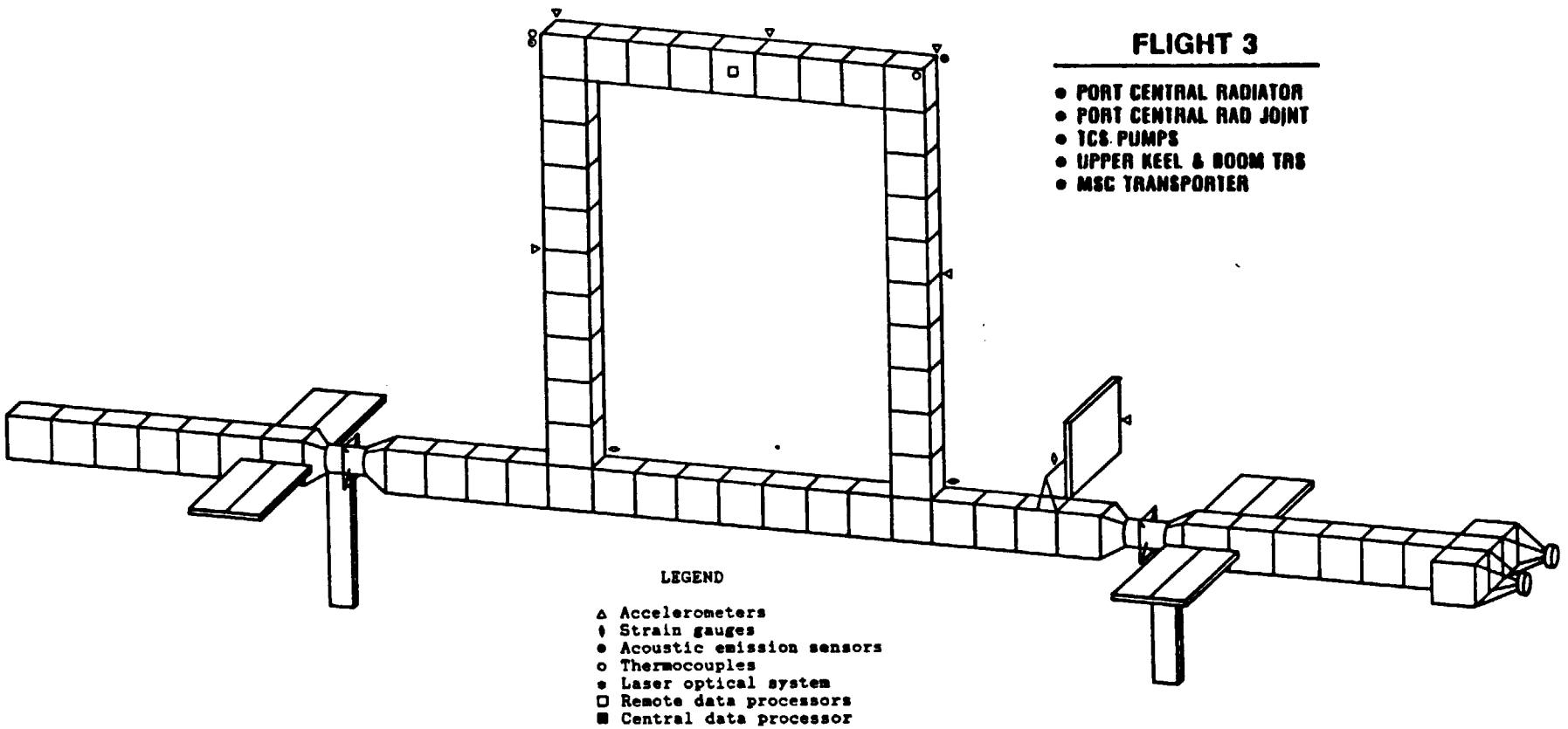


FIGURE 3

Work Package A - Technology Mission/ Experiment Definition

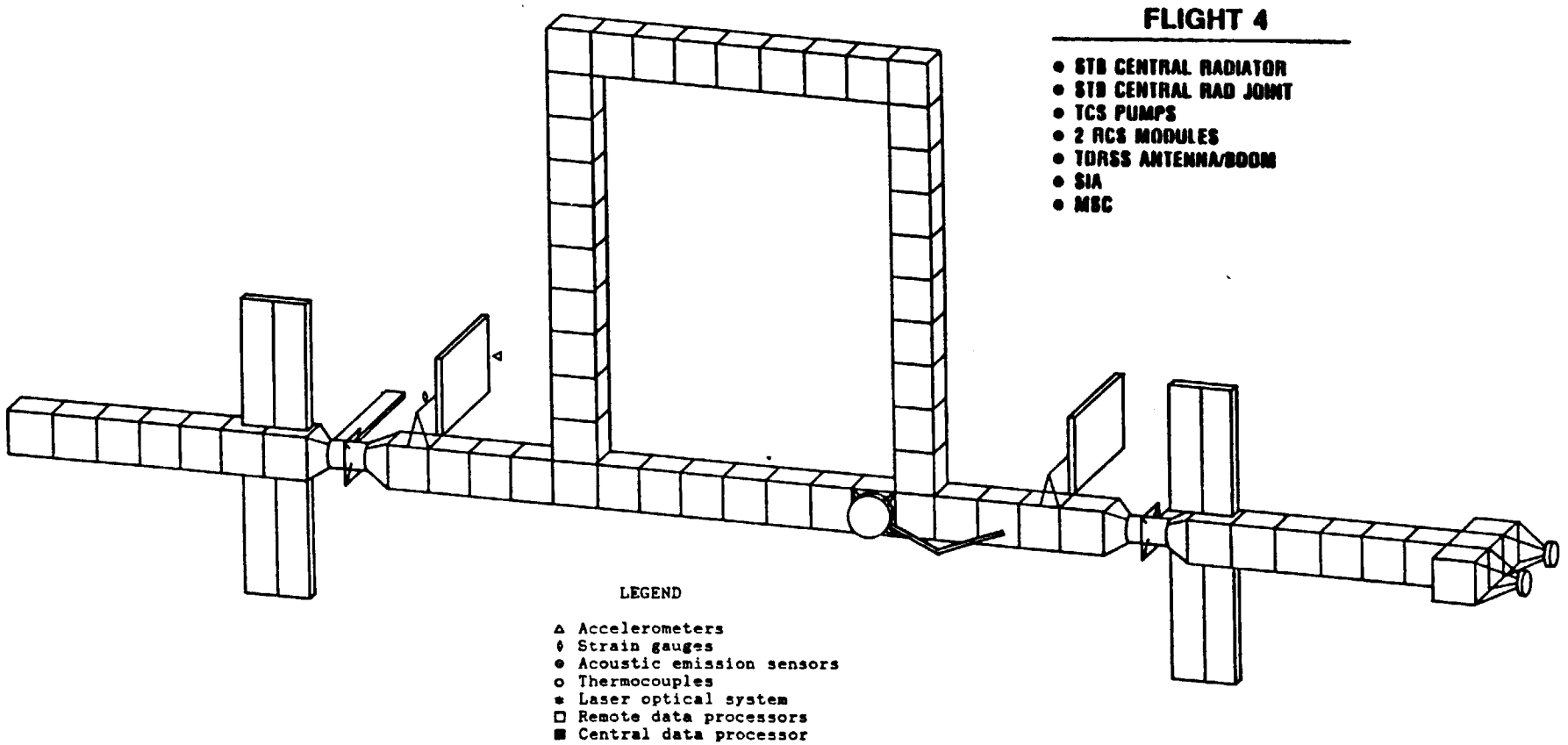
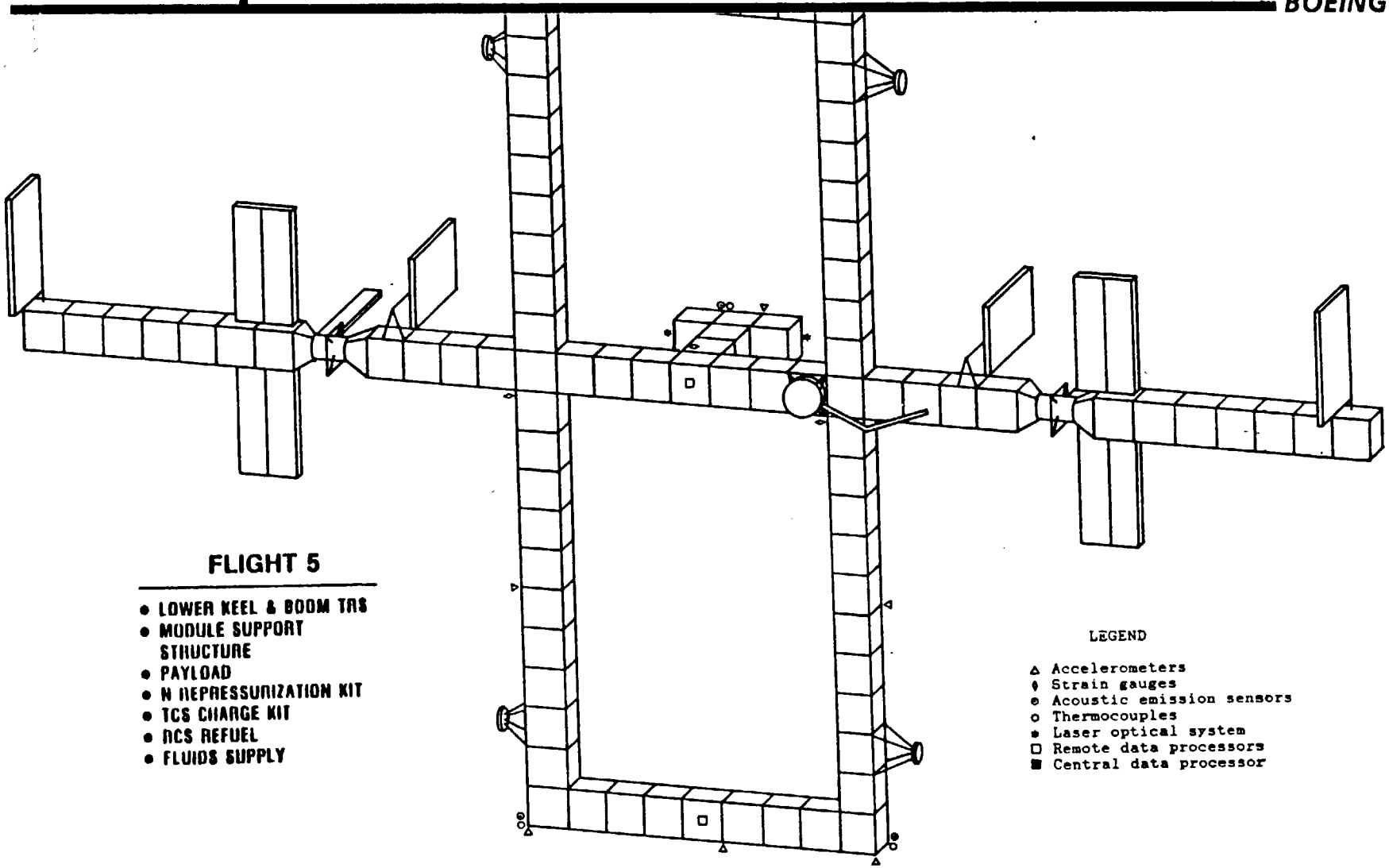


FIGURE 4

Work Package A - Technology Mission/ Experiment Definition



FLIGHT 5

- LOWER KEEL & BOOM TRS
- MODULE SUPPORT STRUCTURE
- PAYLOAD
- N REPRESSURIZATION KIT
- TCS CHARGE KIT
- RCS REFUEL
- FLUIDS SUPPLY

LEGEND

- △ Accelerometers
- ♦ Strain gauges
- ⊕ Acoustic emission sensors
- ○ Thermocouples
- ✱ Laser optical system
- □ Remote data processors
- ■ Central data processor

FIGURE 5

The first module is attached during Flight 6 (Figure 6). Accelerometers in the module or attached to the module measure its rigid body response. The module structures are very rigid compared to deployable components and the truss. Therefore it is expected that they will behave as rigid bodies.

The other part of the task was to identify resource requirements for these flights (Figure 7). We looked at the power requirements of the instrumentation, the volume requirements, mass requirements, and data storage requirements. It is obvious that most of the instrumentation is delivered on the first few flights. On later flights, less and less instrumentation is needed.

This structural performance experiment will become a valuable tool in verifying the analytical predictions of the dynamics of the Space Station, and to determine the dynamic behavior the Space Station during its mission. Any questions?

Bob Walker, NASA/MSFC: Have you established any performance requirements on the accelerometer?

Gates: We've postulated the use of some of those accelerometers which you've seen mentioned before, such as the Sundstrand QA 2000. You want to measure accelerations on the order of 10^{-5} g's, because since we aren't exciting the structure on purpose, the ambient excitations are going to be fairly small, and we will have to measure some very small accelerations.

Question: I think that's probably not quite good enough for what I have in mind; do you have the possibility of ascertaining where the center of gravity of the array is located by looking at the outputs of the accelerometers?

Gates: No, but Ken Demel mentioned that that sort of thing is being postulated, comparing the torque inputs to the response of the Space Station.

Work Package A - Technology Mission/ Experiment Definition

SPACE STATION

BOEING

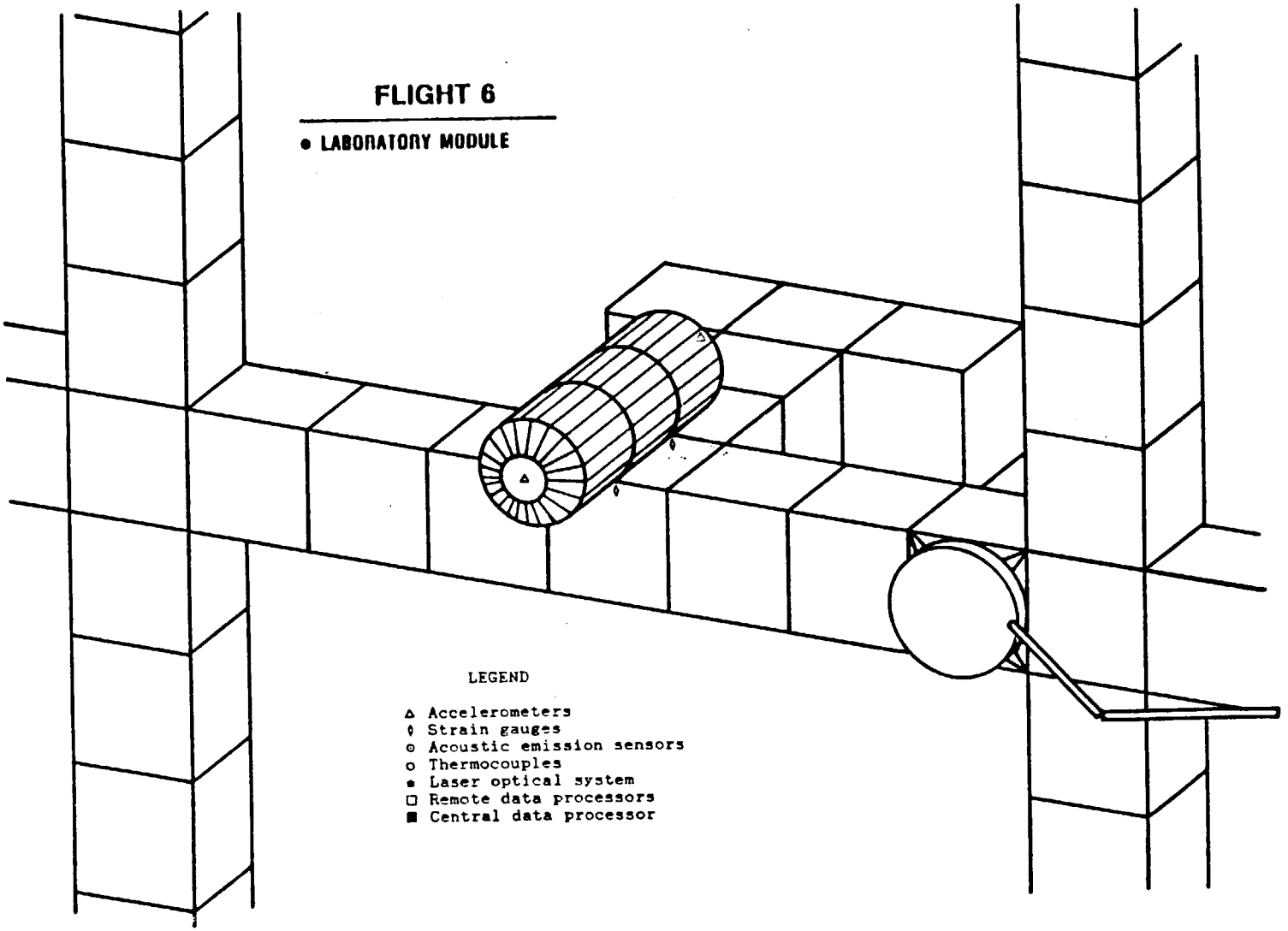
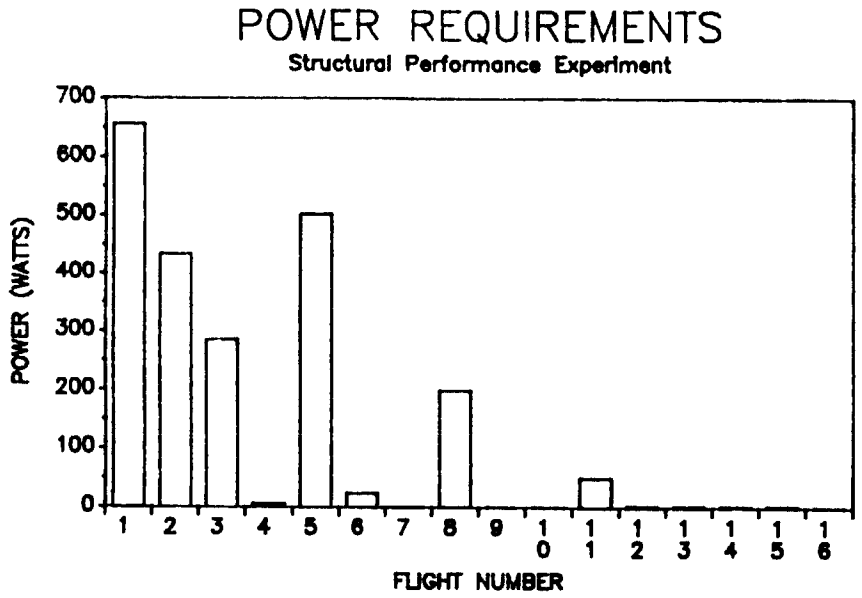
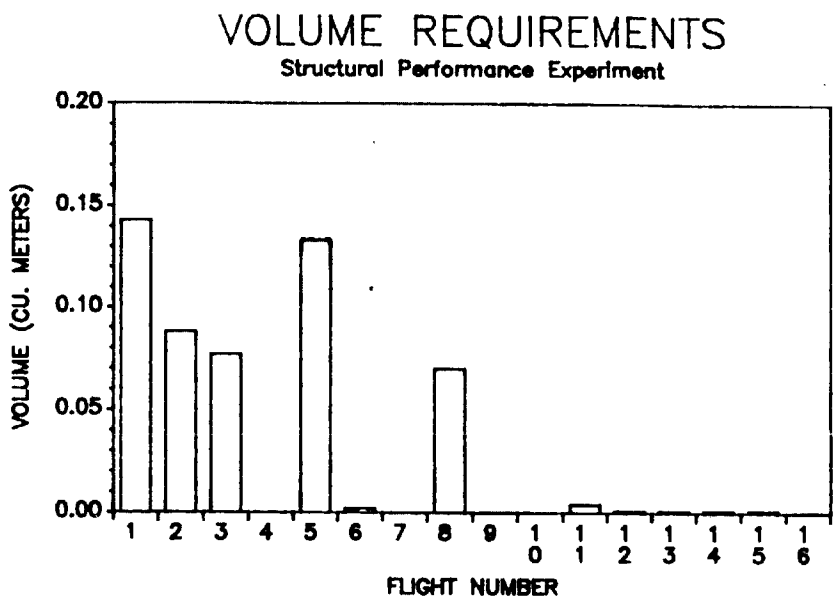
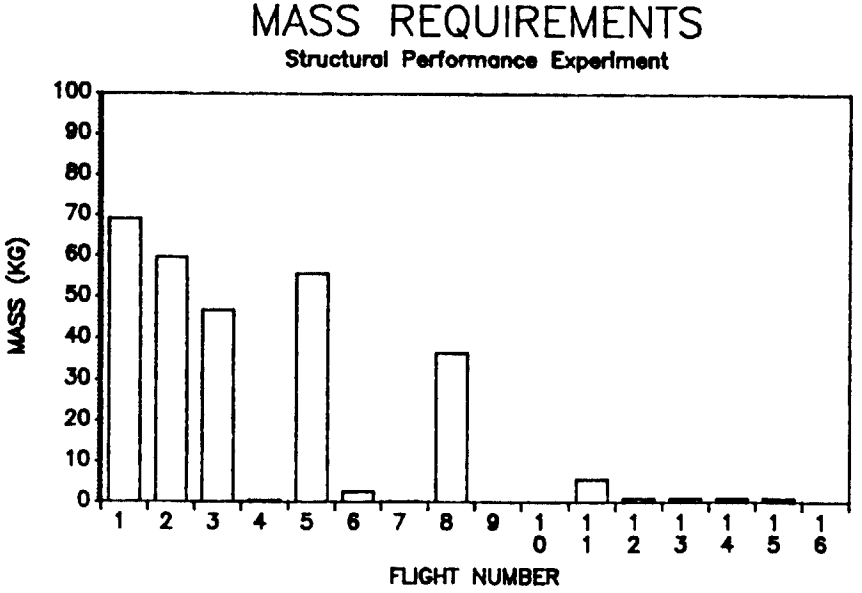


FIGURE 6


POWER REQUIREMENTS
Structural Performance Experiment
POWER (WATTS)
0
100
200
300
400
500
600
700
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FLIGHT NUMBER


VOLUME REQUIREMENTS
Structural Performance Experiment
VOLUME (CU. METERS)
0.00
0.05
0.10
0.15
0.20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FLIGHT NUMBER


MASS REQUIREMENTS
Structural Performance Experiment
MASS (KG)
0
10
20
30
40
50
60
70
80
90
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FLIGHT NUMBER

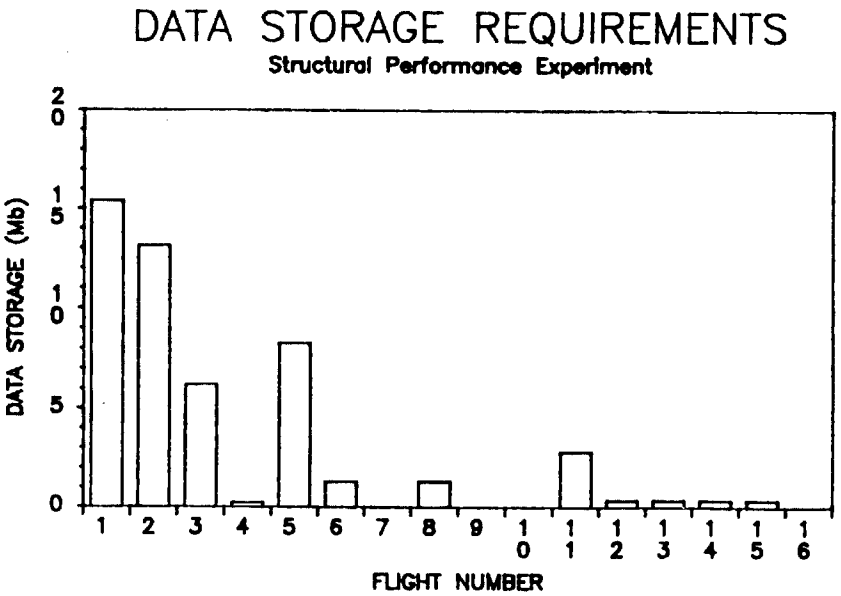

DATA STORAGE REQUIREMENTS
Structural Performance Experiment
DATA STORAGE (Mb)
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
FLIGHT NUMBER

FIGURE 7

Question: You had some laser sensors. Are they measuring range to targets at specific points on the structure?

Gates: Yes. The purpose of those sensors was to measure the as-built accuracy of the structure and also to measure the thermal deformations as it goes in and out of the shadow.

Question: What kind of data reduction scheme will you use to analyze the data?

Gates: We don't have any. We haven't calculated any typical responses of the structure; our job is to identify the experiment, and we haven't postulated the data reduction schemes.