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NASDA's New Test Facilities for Satellites and Rockets

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Recently, the space development activities for the practical purposes are progressing in the world. For the development of large satellite, rocket, space station and spaceplane, new technology at the field of space simulation has been required. Based on the results of our basic study and investigation on the technology, National Space Development Agency of Japan (NASDA) has decided to construct the integrated environmental and structural test facilities for the future large satellites. Presently , these facilities are under construction . This paper presents the outline of NASDA's new test facilities and some technical considerations , especially for the unique vibration test facility .

1. Introduction

Recently, we are developing H-2 rocket, 2 ton class large geostationary earth orbit (GEO) satellite Engineering Test Satellite Ⅵ, (ETS-Ⅵ) Free- Flyer and Japanese Experimental Module (JEM) of the space station under the co-operation with NASA and ESA , for the 1990's space applications . These future spacecraft become larger in dimensions and heavier in weight . With the development of advanced spacecraft, more severe test specifications are required for the environmental and space simulation test facilities .

The environmental and space simulation tests for our satellites and rocket components are performed at Tsukuba- Space- Center (TKSC) of NASDA . Our current facilities were constructed for the satellites which are launched by N and H-1 rockets . And the requirements for the future large spacecraft are beyond the capacities of these facilities .

From this situation ,we have studied environmental technologies for the future large satellites for several years. In 1983, we started to make the preliminary investigation on the future test facilities .
In 1985,we got test engineer's opinion from the space industries in our country.

Based on the groval evaluation of the results of our studies, we made a construction plan of new environmental test facilities ,in 1986 .

Presently,our new facilities are under construction at TKSC . And it will be initially used for the development tests of ETS-Ⅵ in 1989.

In this paper , our philosophy for new test facilities, the outline of each facility and in paticular, some of the technical uniqueness of vibration test facility are discussed.

2. Philosophy of New test Facilities

Fig. 1 shows total system of our new test facilities.
Our philosophy is to perform all tests of a spacecraft in one building, which we call " integrated test building " .

ESA/ESTEC and IABG have a plan to improve test capabilities by adding some equipments and facilities for next generation satellites.
And CNES/INTESPACE , The Institute of Space and Astronautical Science of Japan (ISAS) have also attractive concentrated test facilities.

However, our new test systems and facilities will be one of the most advanced ones in the world . Next generation environment facilities will have this tendency.

Here, we discribe the requirements for our facilities.

(1) High capacities for large spacecraft in the 1990's.
(2) Ability to perform 4 spacecraft tests at once .
(3) High efficiency of test operation.
(4) Low cost of test operation.
(5) Applicability to future space business.
(6) Environment test levels specified from H-2 Rocket.

Based on the above requirements,we designed and made the building layout as shown in Fig . 2 .

Due to above requirements , the performance of our facilities are summarized as shown in Table 1.

Table 2 shows the full schedule about test facilities total plan.

Fig .1 Total System of New Test Facility

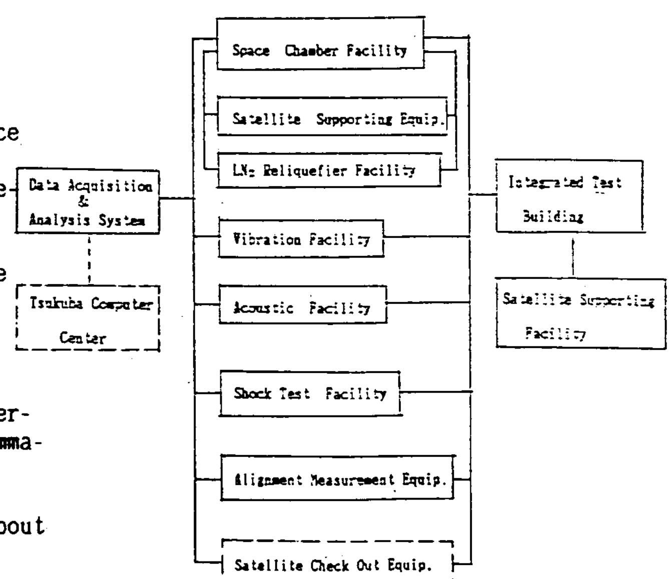


Table .1 Features of New Test Facilities

1 . Target -----2 Ton class satellites (at GEO)
2 . High Efficiency
3 . Can Test Many Satellites at a Time
4 . Low Cost
5 . Open to Many World's Users

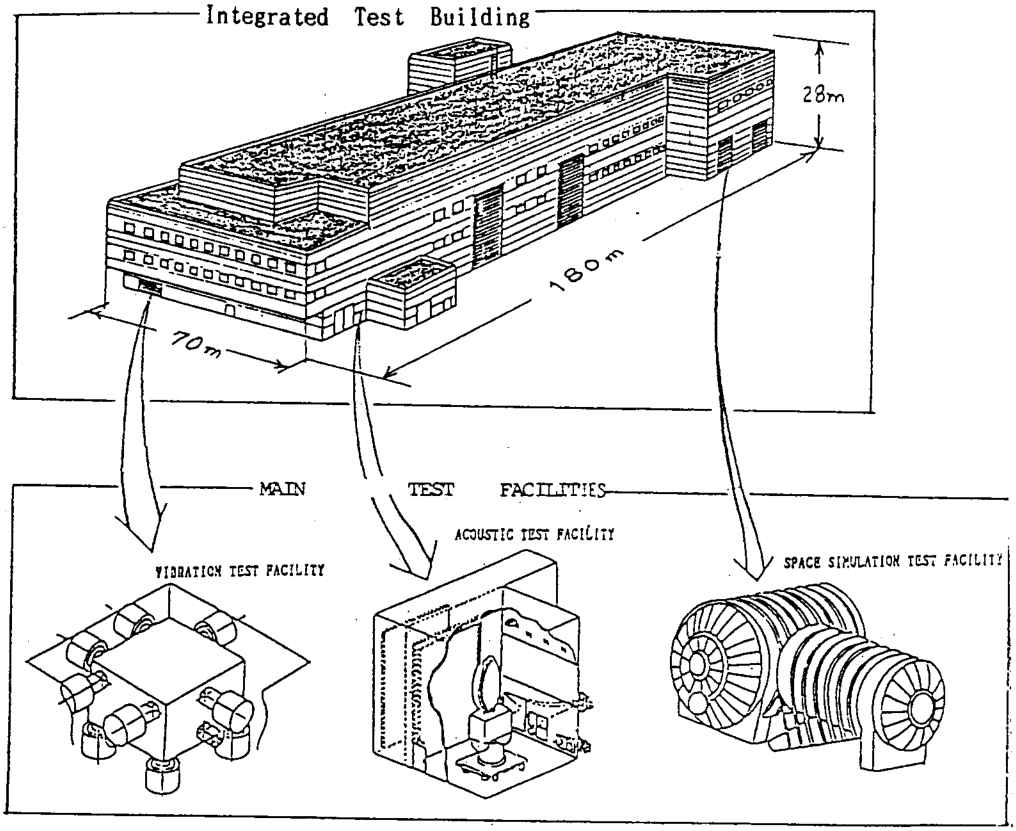
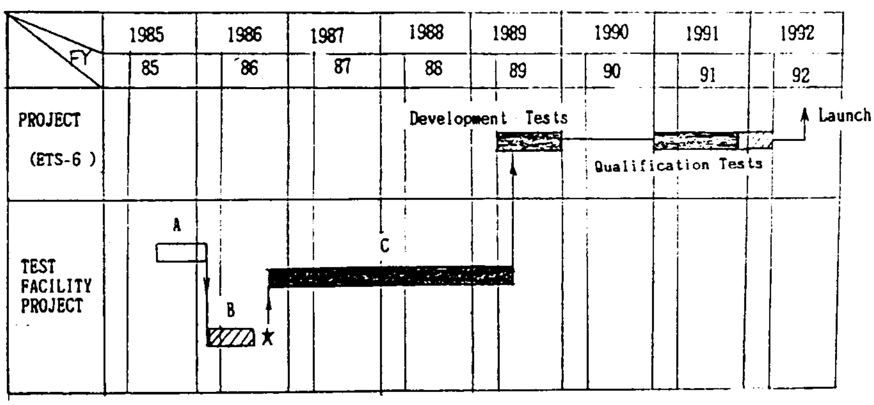


Fig .2 New Test Facilities and Integrated Test Building

Table .2 Project Plan of Integrated Test Facility



Total Span ---- 4 Years (7 Years including basic studies)

PHASE

A : Preriminary Studies and Test System Plan

B : 1 NASDA's detail investigation including industries' opinion

2 Project Planning

3 Decision of contractors

C : Construction of facilities .

3. Vibration Test Facility

Fig. shows the bird's-eye view of the vibration test facility, which is a three dimensional vibration system . We can perform the vibration tests of three directions separately without removing the test specimen from the table.

Therefore , we can complite the test for a spacecraft shorter period than that of conventional test facility ,which results in high operational efficiency .

The new vibration system consists of 4 vertical and 3 horizontal shakers for each axis , totally 10 shakers .
From the results of our trade-off studies, we decided to adopt electrodynamic shaker rather than hydrodynamic one,from the operational and control point of view .
The test table has 3mX3m size , which is made of aluminum alloy and supported through 12 hydrostatic joints . We designed the joint to move in 5 degrees of freedom . Using the table support system composed of these joints the control system becomes less complicated .

The specification of the vibration facility is shown in Table 3 .

Here , we explain some technical features of the system .

(1) Principle of the Supporting System

Fig .4 shows a free body diagram of the rigid supporting table movement .
To move the rigid table in one direction , two surfaces of the table in parallel with the direction of the motion have to be supported at two points in one surface and at three points in another surface.
Our supporting system adopts this principle .

However , for the horizontal slidings in X and Y direction , one more points is added to the above three points for resisting the rolling moment forces due to the test specimen .

Fig .5 shows the location of the spherical pad bearings which are used at each point due to the above principle .

(2) Mechanism of Spherical Pad Bearing

The hydrostatic joint designed for our system , which we call " spherical pad bearing " , restricts only one degree of freedom of the motion .

Fig .6 shows a cross section of the spherical pad bearing .
As shown in Fig .7, the spherical pad bearing has five degree of freedom of the motion . In this joint , one degree of freedom of the motion , which is the motion along the connecting line between the joint base and the supporting table, is restricted .

One of the technical key points in our system is to develop the hydrostatic joint, especially to increase the rigidity of the joint . Presently , the rigidity in the axial direction of the joint is designed to be approximately 8×10^7 kg/mm .

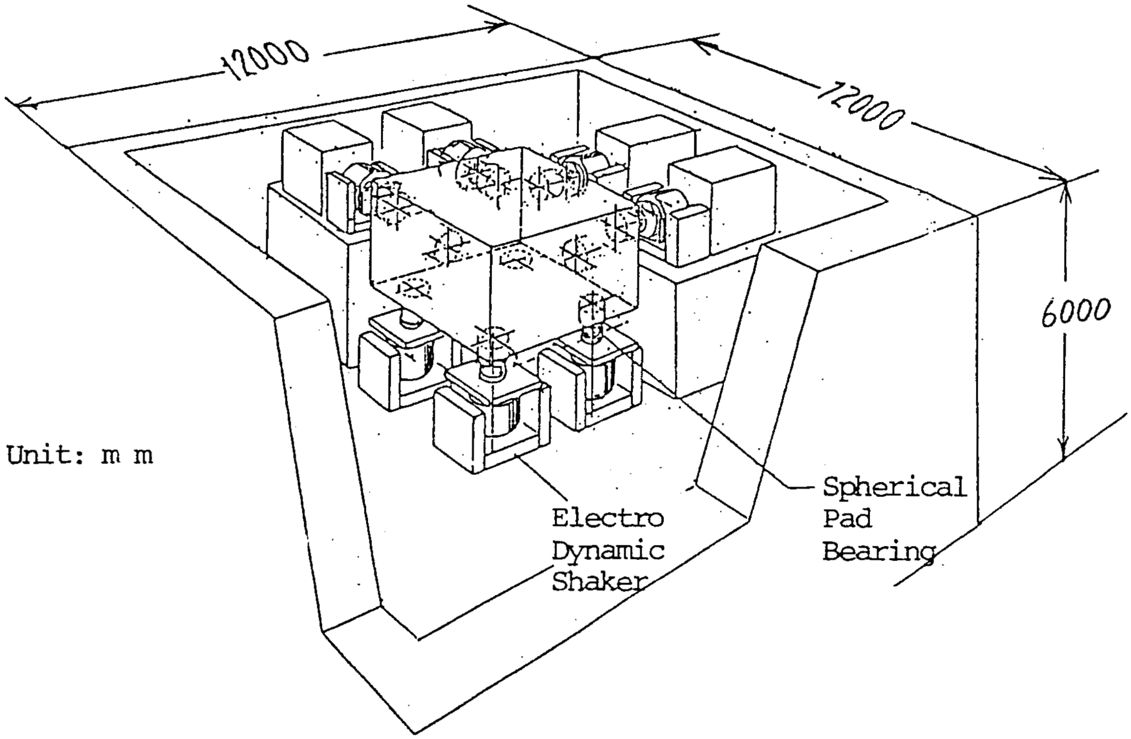


Fig. 3 Vibration Facility (Shaker and Table Assembly)

Table. 3 Vibration Test Facility Specification

TOTAL PERFOMANCE	3 DIRECTIONAL SHAKER SYSTEM WEIGHT CAPABILITY : 4.5 tons (9,900 lbs.) FREQUECY RANGE : SINE 5 - 100 Hz RANDOM 5 - 200 Hz (Low Level) TRANSIENT OVERTURNING MOMENT CAPABILITY : 60 ton-m (434,000 ft.-lbs.)
SHAKER	LDS ELECTRODYNAMIC SHAKER VERTICAL ; 9.5 tonF X 4 shakers HORIZONTAL ; 9.5 tonF X 3 shakers X 2 directions (21,000 lbs.)
TEST TABLE	DIMENSION: 3 m × 3 m : (9.8 X 9.8 ft.) Aluminum alloy
CONTROL	Genrad, digital for amplitude control LDS, analog for current-phase control

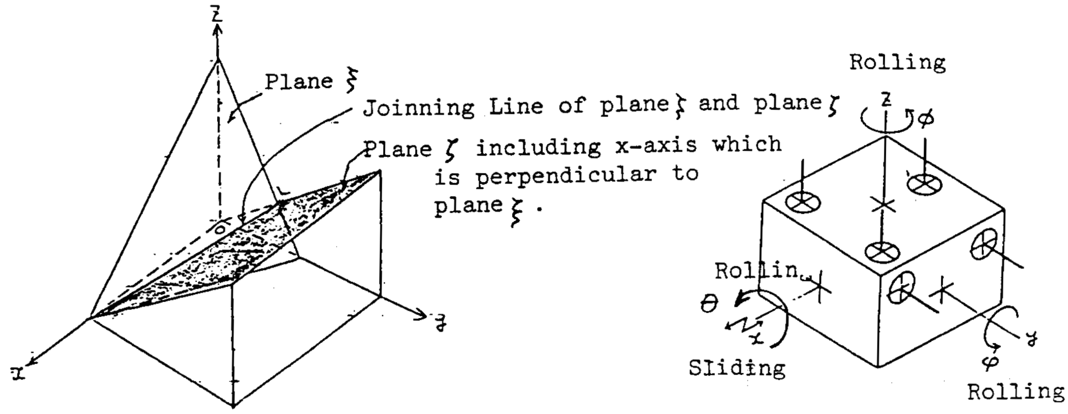
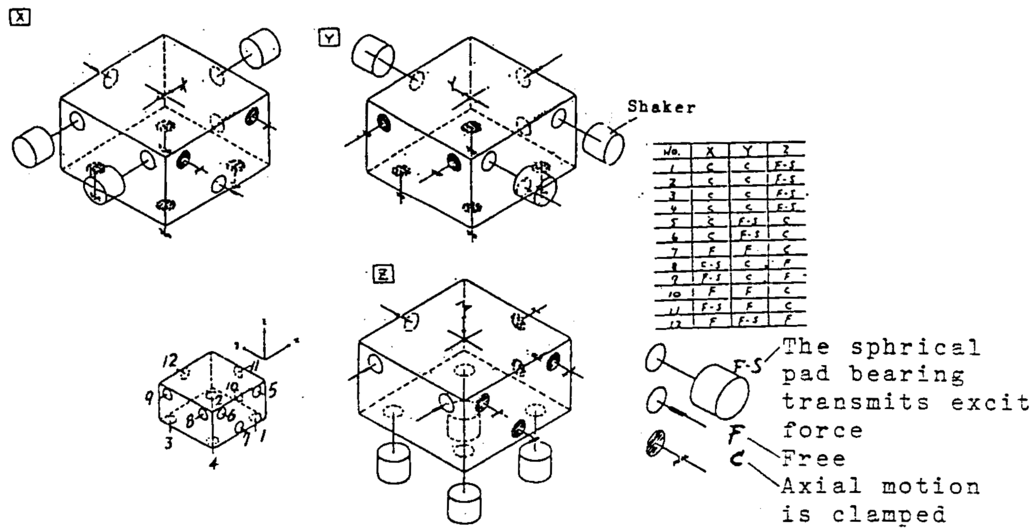


Fig. 4 Principle of Supporting in the Free Space



No.	X	Y	Z
1	C	C	F-S
2	C	C	F-S
3	C	C	F-S
4	C	C	F-S
5	C	F-S	C
6	C	F-S	C
7	F	F	C
8	C-S	C	F
9	F-S	C	F
10	F	F	C
11	F-S	F	C
12	F	F-S	F

Fig. 5 Distribution of the Spherical Pad Bearings and their Function for Each Excitation Axis

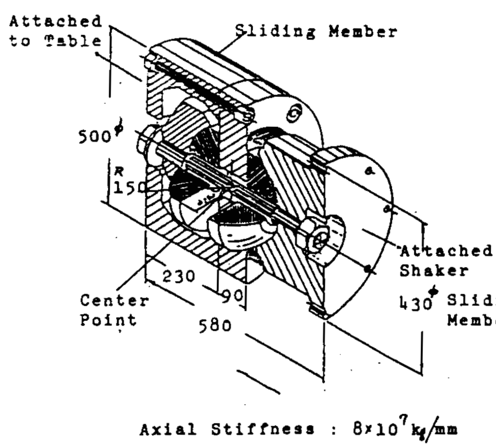


Fig .6 Spherical Pad Bearing

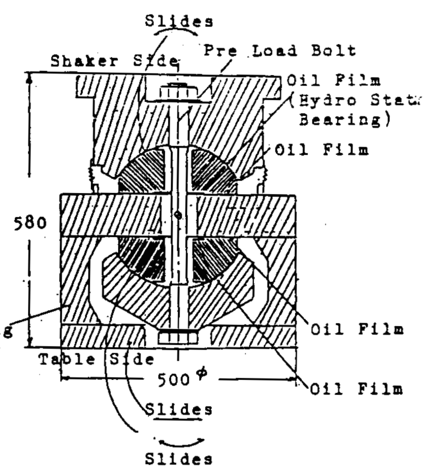


Fig. Cross Section of Spherical Pad Bearing

4 . Space Simulation Test Facility

Fig.8 shows the space simulation test facility , which enables us to perform solar simulation test , IR simulation test , and vacuum thermal cycle test .

The vacuum chamber is a horizontal hammer type one with a full- open-door . This type of door enables us to use the chamber volume efficiently , because it is allowed to set a large specimen up to the chamber diameter .
The efficient chamber volume , $13^{\phi}m \chi 16^{L}m$, was determined from the requirements of spacecraft and precision of solar simulator design .
The efficient beam diameter of the solar simulator is 6 m .

One of the most advanced technologies adopted in this facility is the collimation mirror composed of glass coated CFRP segments . This mirror is light weight . Therefore , it requires a simple mechanism for the tempereture control as shown in Fig .9 .

And to operate the chamber system at low cost , we reuse the vaparized N_2 through the LN_2-Reliquefier facility .

The specification of the space simulation test facility is shown in table 4 .

5 . Acoustic Test Facility

Fig .10 shows the acoustic test facility . In this facility , we adopted a compressed air type system which is the same type as the current facility and is superior to the GN_2 blow - down type system in operational test efficiency .

The maximum overall sound pressure level (SPL) is 151dB, and one-third octave band spectrum shaping is performed with the degital controller ,which consists of a redundant system .

The volume of the new reverberation chamber is approximately 1600 m^3 (10.5m×9.0m ×17.0^{H}m) . And also this facility is provided with a supporting cart for large spacecraft .

The specification of the acoustic test facility is shown in Table 5 .

6 . Data Acquisition and Analysis System

Fig . 11 shows the data acquisition and analysis system . This system is a kind of data processing center with the LAN , which consists of data analysis and management computers and terminals at each test area .

We can use this system not only to process the data acquired at each test and to establish the data base of spacecraft design and tests, but also to storage ourselves technical potential.

The new facility has high speed data processing , and the data memory of 40 GB .laser disk .

Table 6 shows the characteristics of the data acquisition and analysis system .

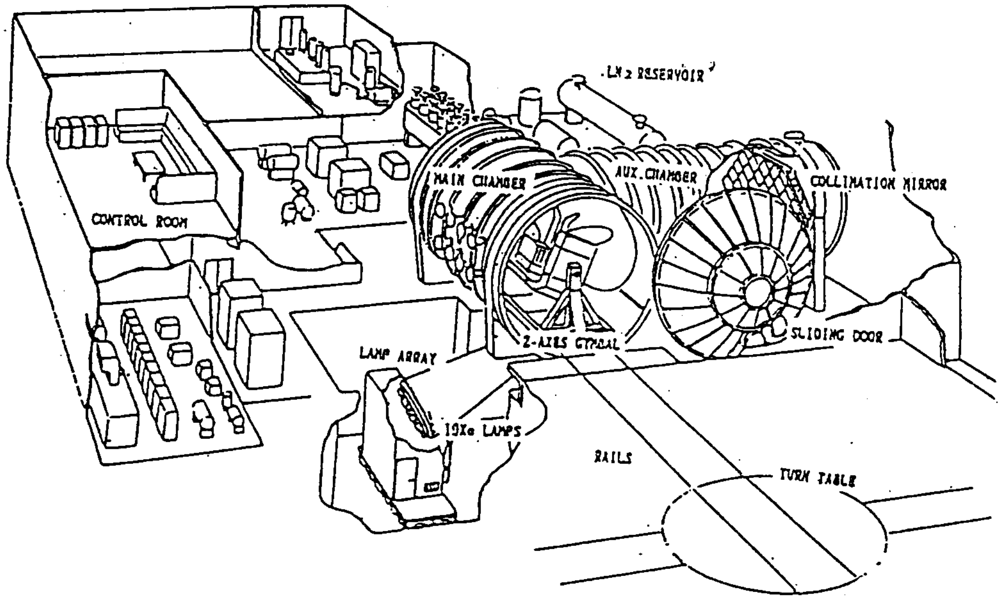
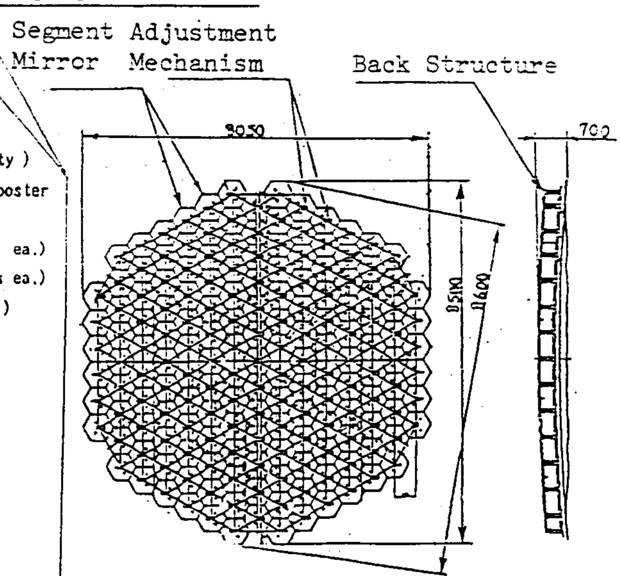


Fig. 8 Space Simulation Test Facility

Table. 4 Space Simulation Test Facility Specification

VACUUM VESSEL	HORIZONTAL HAMMER SHAPE USABLE VOLUME : 13 m diam. X 16 m long
VACUUM SYSTEM	ULTIMATE PRESSURE : 1 X 10^{-7} torr within 16 hours (empty) ROUGHING SYSTEM : 4 Oil Rotary Pumps and Mechanical Booster Pumps HIGH VACUUM SYSTEM : 3 Turbomolecular Pumps (4.900 l/s ea.) 4 He Cryosorption Pumps (28.000 l/s ea.) 2 He Cryo Pumps (1.700.000 l/s ea.)
SHROUD SYSTEM	100 K (LN_2) -100 to 60°C (GN_2)
SOLAR SIMULATOR	BEAM DIAMETER : 6 m INTENSITY : 1.3 solar constant (Max.) UNIFORMITY : ± 6% at Reference Plane SOURCE : 30 kW Xe lamp x 19 COLLIMATION MIRROR : Glass coated CFRP segmental mirror (Al deposited)
MOTION SIMULATOR	WEIGHT CAPABILITY : 5 tons SPIN RATE : 0 - 10 RPM (continuous and step) ATTITUDE RANGE : Horizontal ± 90 deg.



Shape	Spherical (163 Hexagonal Segments)
Material	Glass coated CFRP + Al honeycomb
Reflecting Surface	Aluminium with SiO_2 Coating

Fig. 9 Collimation Mirror

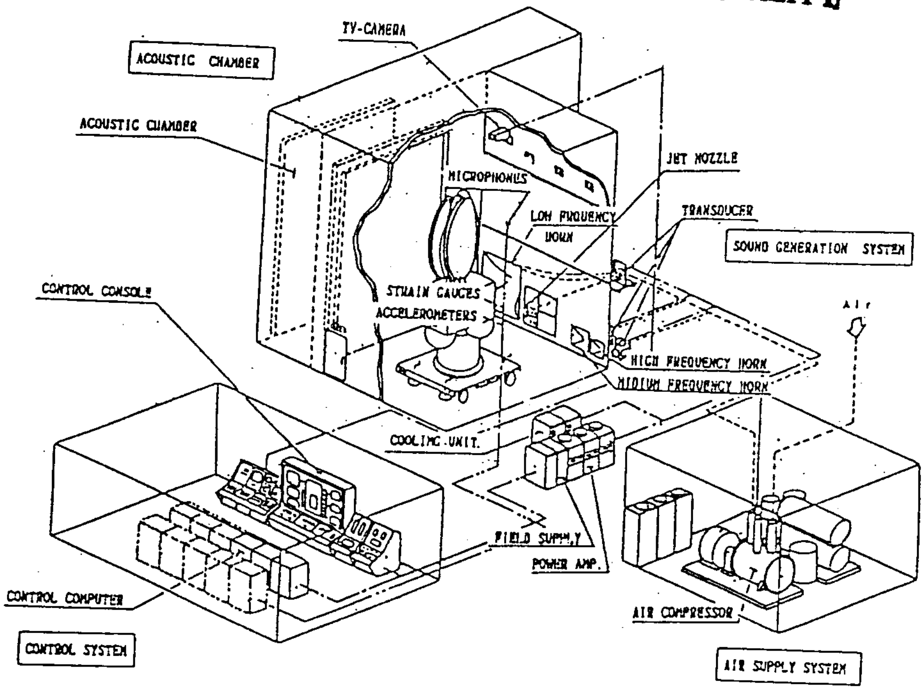


Fig. 10 Acoustic Test Facility

Table 5 Acoustic Test Facility Specification

TOTAL PERFRMANCE	COMPRESSED AIR · SYSTEM SOUND PRESSURE LEVEL : 151 dB (O.A.) SPECTRUM RANGE : 25 Hz - 10 kHz (1/3 oct.band width)
AIR COMPRESSOR	AIR FLOW RATE : 245 Nm^3/min. MOTOR : 1440 kW
SOUND GENERATOR	TRANSDUCER : EPT-200 (10kW) X 3 EPT-1094 (10kW) X 4 JET NOZZLE (0.2kW) X 1 HORN : 25 Hz X 1 100 Hz X 1 200 Hz X 1
CONTROL	1/3 oct.band DIGITAL CONTROL
ACOUSTIC CHAMBER	DIMENSION : 10.5 W X 9.0 D X 17.0 H (m) ACCESS DOOR : 7.0 W X 13.0 H (m) approx. VOLUME : 1,600 m^3 (56,500 ft^3)

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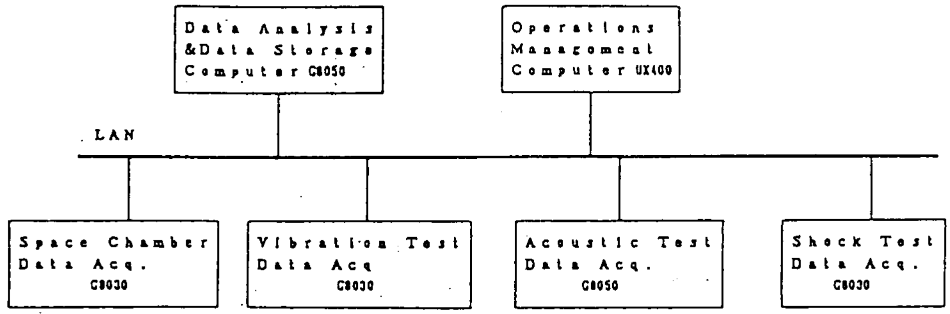

*Feature
- Using the LAN System
- Compatible with each other
- High Speed Data Processing
- Large Digital Data Memory (Laser Disk 40GB)

Fig. 11 Data Acquisition and Handling System

Table. 6 Data handling System Characteristics

1. VIBRATION

Data Acquisition

Channel--------ACC. 300ch.
Strain 50ch.
Frequency Range--5~100Hz (Sin.)
5~200Hz (Ran)
Sampling Rate ---800 sam/ sec

Data Analysis

FFT , PSD , Trancefer Func. Ana.
Wave Form Analysis
Notch Level Analysis
Analysis and Print Out Time--
44 min. 350 cH (FFT,PSD,f-g)

2. SPACE CHAMBER

Data Acquisition

Channel-------Temp. 800 cH .
Calorimeter 300cH.
Analog Sig. 50 cH .
Digital Sig. RS232Cx2
Scanning Speed--10 msec, 100m sec/cH
Measurement Interval -- 2 min.

Data Processing

Scan Print, Senser vs. Time Print and Plot
Average Print ,ΔT/t Print and Plot
Equilibrium Search Print , Limit Check
Min. Max. of Sensor Defind
Calolimeters Process,
Equilibrium Frequency Bar Graph,
Prediction of Equilibrium ,

3. ACOUSTIC

Data Acquisition

Channel---ACC. 200 cH.
Strain 30cH.
Microphone-12cH.
Frequency Range
ACC. 5~2kHz
Sampling Rate
ACC.&STR. 8k/sec
Microphone
40 k / sec

Data Analysis

1/1, 1/3 Oct Analysis
PSD, AL-SPL
Transfer Func. Analysis
Analysis and Print Out
Time---25 min. 200cH
(PSD,1/1 ,AL-SPL)

4. SHOCK

Data Acquisition

Channel---ACC. 200cH
Frequency Range
20~10kHz
Sampling Rate
50 kHz Sam./sec

Data Analysis

FFT , SRS ,
Wave Form Analysis
Analysis and Print Out
Time--25 min. 200 cH.
(FFT , SRS ,)

7 . Integrated Test Building

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Fig . 12 shows the integrated test building .
The total-area of this building is about 1800 m² and the layout is shown in Fig. 13 .

There are two test area . One is the static test area and another is the dynamic test area .
The spacecraft test rooms have the cleanness of class 100,000 .
To keep the high cleanness of the building , two types of air lock loading room are adopted for the entrance of satellites and its supporting equipments .
Especially, in this building , a large preparation area is provided to satisfy a variety of user's requirements .

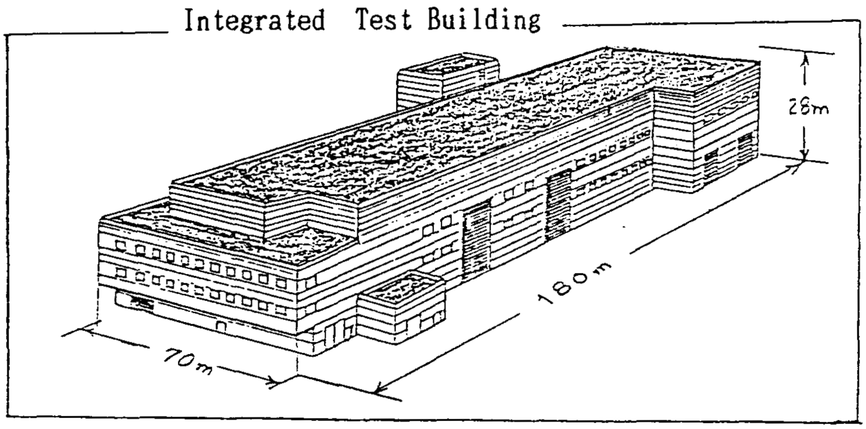

Fig . 12 Integrated Test Building

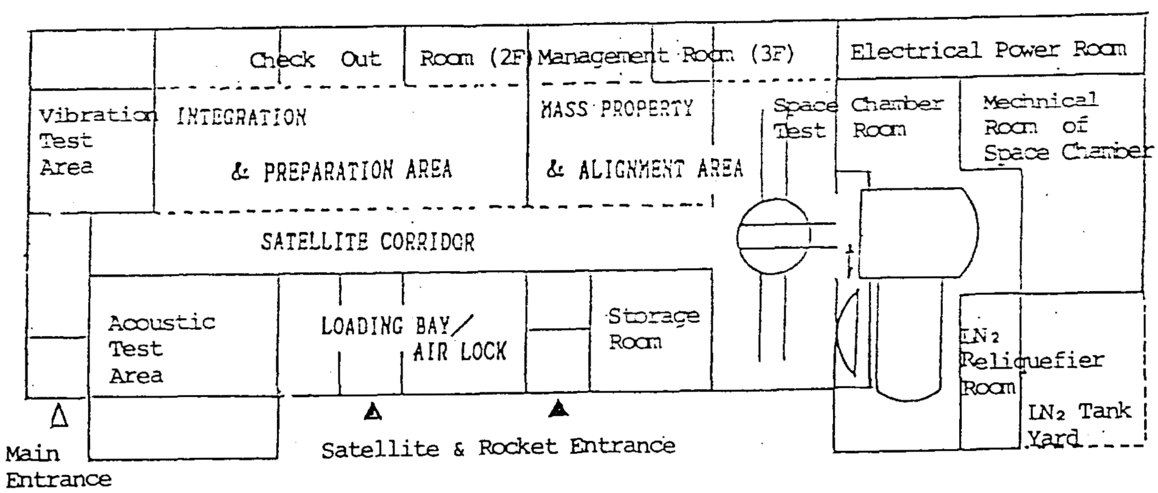

Fig .13 Layout of Integrated Test Building

8 . Conclusions

We presented the outline of NASDA's new test facilities , our philosophy of NASDA's future spacecraft development and some technical key points of our vibration test system .

Our new facilities' "easy and low cost operationability" will answer to the requirements of many users in the world and open a door to the tests of their future large spacecraft .

We will be able to present some detail performances of the facilities at the next chance .