

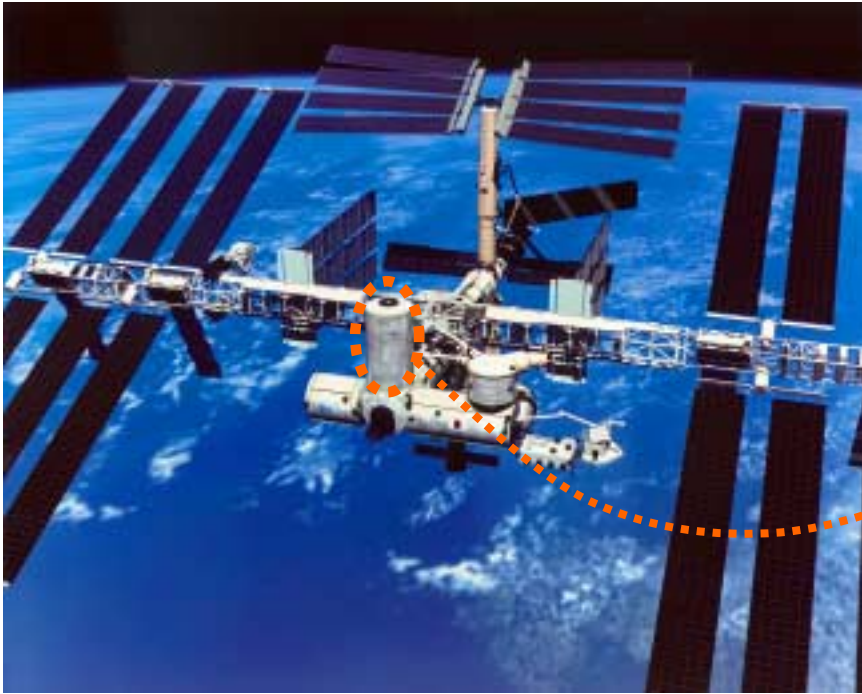
MSC.ADAMS Applications to Space Equipment

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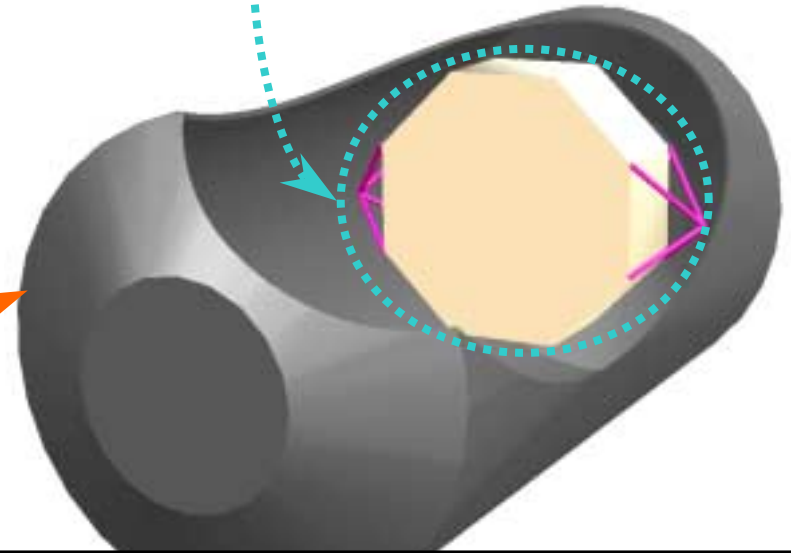
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Centrifuge (Life Science Experiment Module)



ISS: International Space Station

CR: Centrifuge Rotor



CAM: Centrifuge Accommodations Module

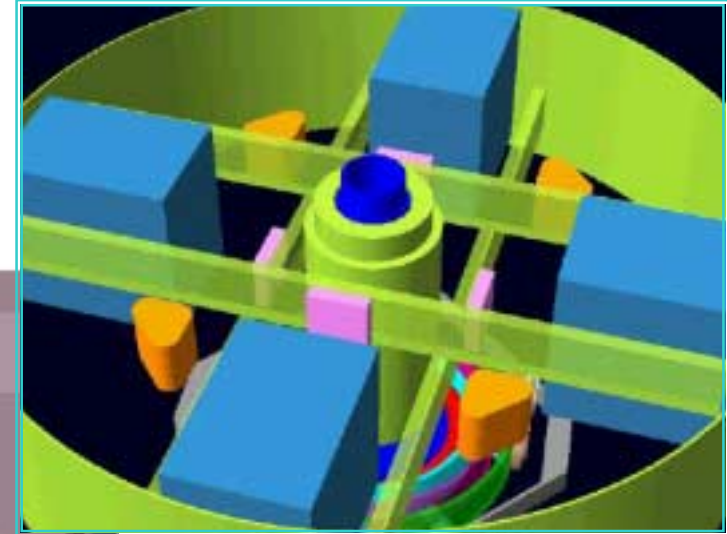
- Newly developing space machinery equipped in ISS in cooperation with NASDA (NT Space/Toshiba) and NASA
- Life cycle experiment on orbit to investigate the effect of gravity on rodent and plant

Technical Issues

To isolate vibration between CR and ISS

Cancel the imbalance in rotor

ABS: Auto-Balancing System

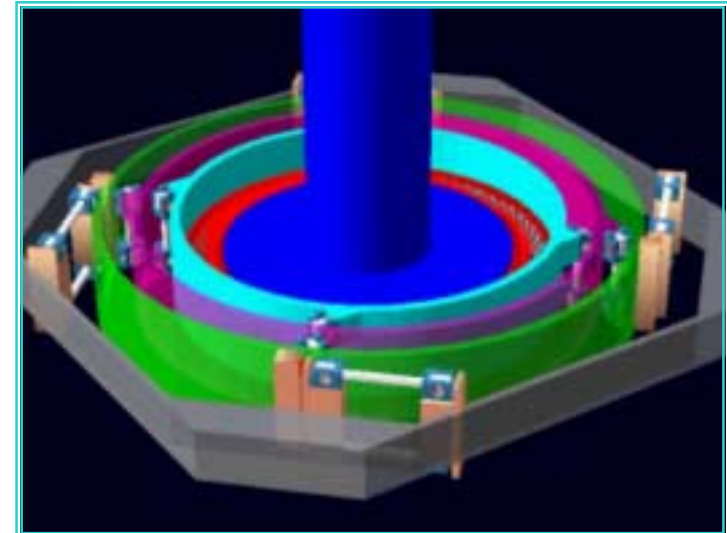


ISS Movement

Rotor-Induced Vibration

Suppress vibration

VIM: Vibration Isolation Mechanism



Requirements for ADAMS Simulation

Simulation technology is indispensable for Space Equipment Design, because we can't verify its performance in space by ground test.

Simulate vibration isolation mechanism (spring, damper)

Simulate accidental events

Response for external force

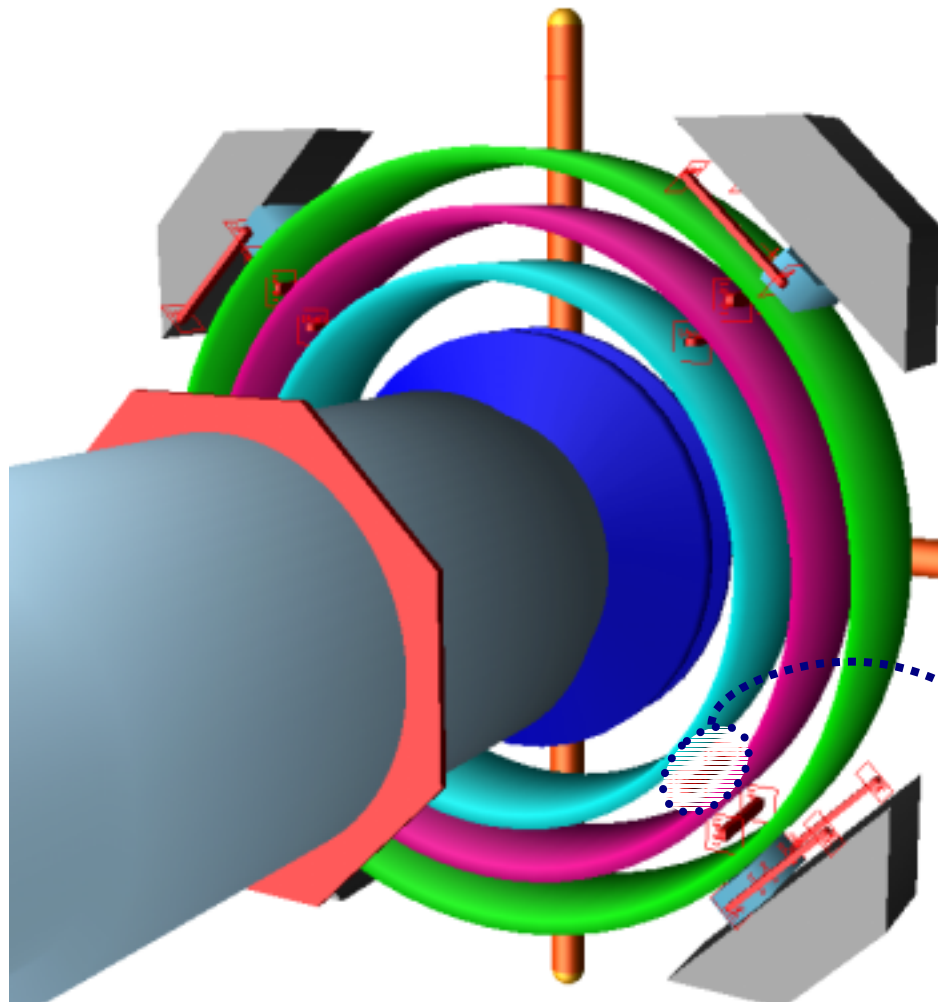
Simulate gyro-moment effect by orbital movement

Visualizations of complex mechanisms and their movement

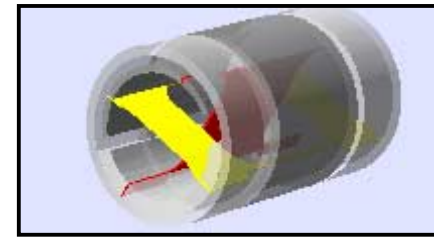
Simulate characteristics of actuators

Modeling of Vibration Isolation Mechanism

**Simplification of complex structure by
FEM/Experiment**



Modeling for ADAMS Simulation



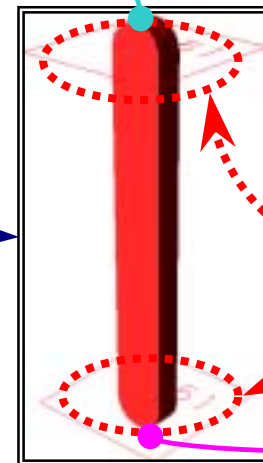
Free-Flex Pivot



Pivot Link

FEM/Experiment

Ring1



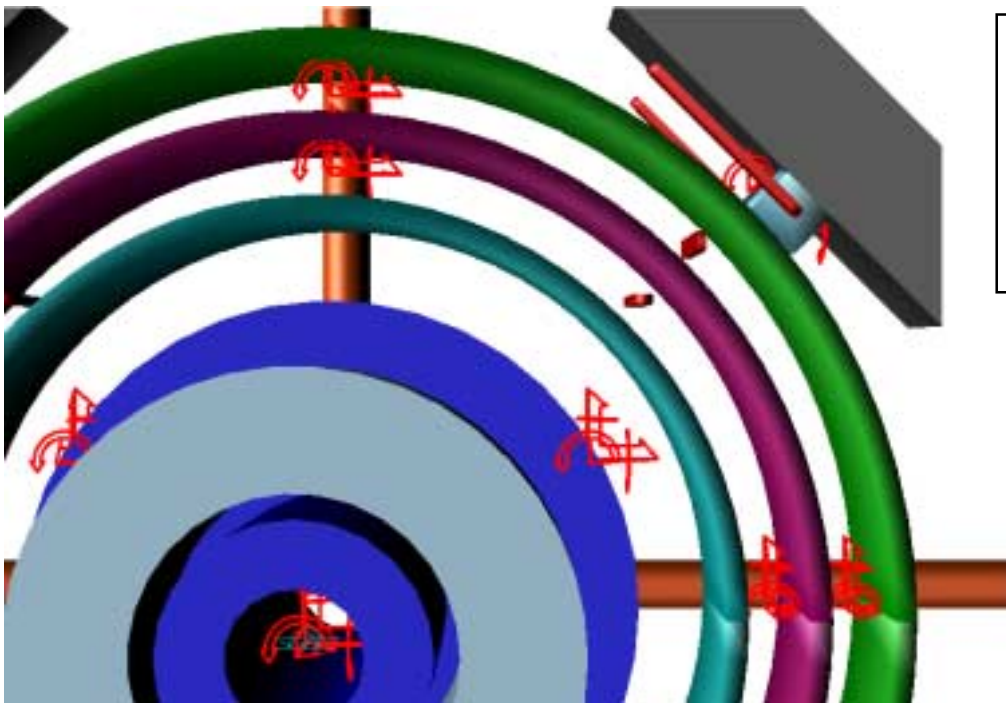
Rigidity
Matrix

Ring2

Modeling of Actuator and Passive Damper

Modeling Actuator and Passive Damper by General Force

- Actuator: Definition based on simulating controller
- Passive Damper: Define frequency domain characteristics by Transfer Function and Linear State Equation



Define control by ADAMS

1. By System Element
2. By Standard Control Blocks
3. By User Subroutines



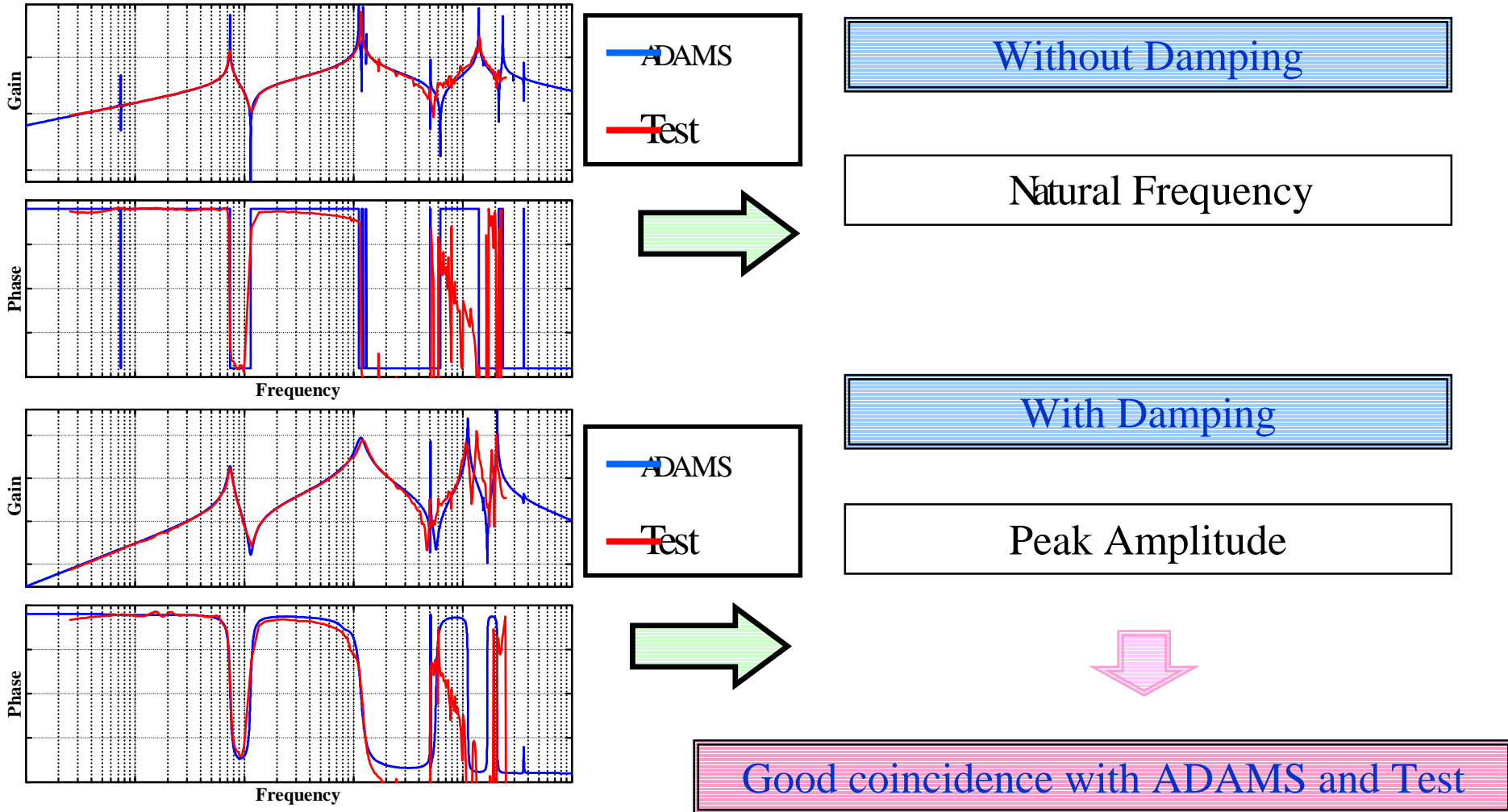
Neither satisfactory



ADAMS/Controls!!

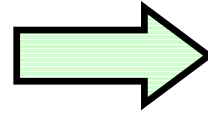
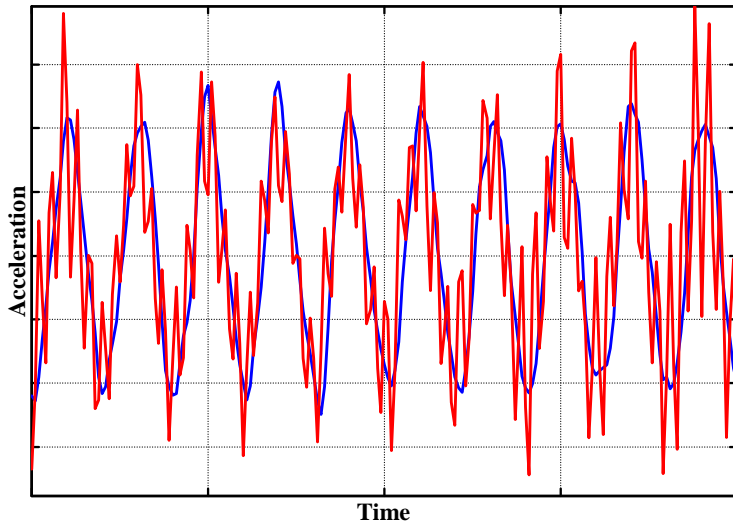
Verification of ADAMS Model (Frequency Domain)

- Verification by comparing ADAMS simulation results and ground test results

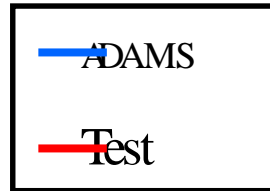


Verification of ADAMS Model (Time History)

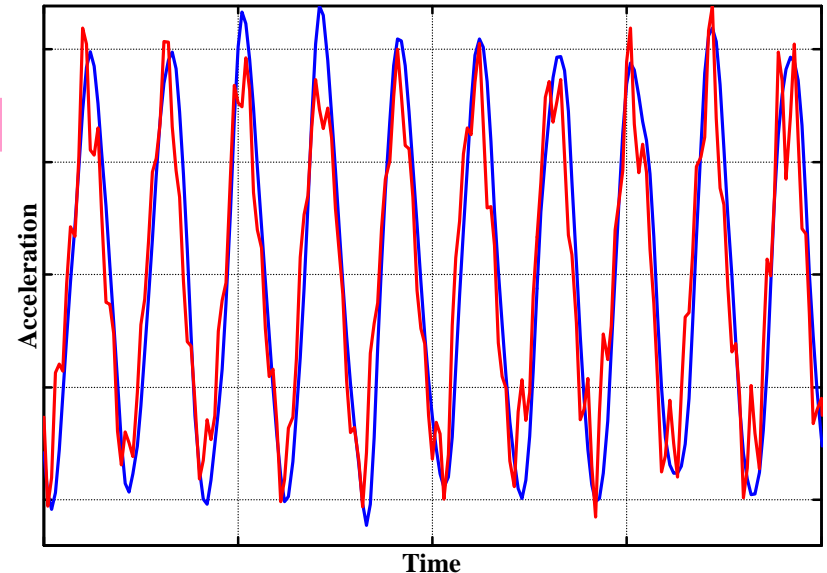
Raw Test Data



Neglect local mode frequency
by low-pass filtering



Filtered Test Data

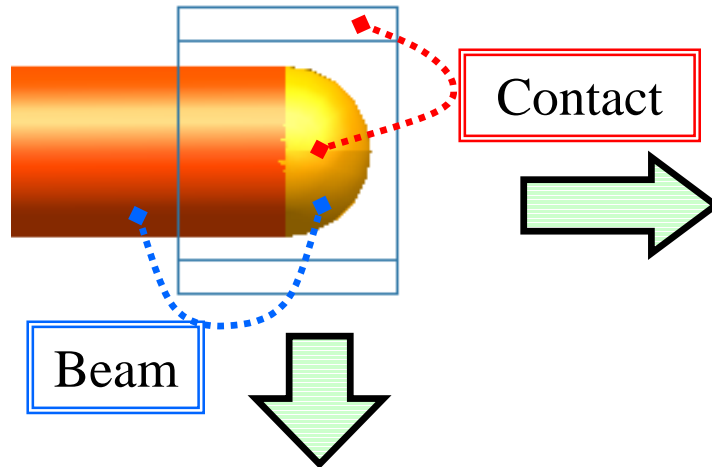


ADAMS can simulate Test Data.

The ground test equipment is more complex than the space equipment, because it has a special device to compensate the gravity effect. This means that the simulation on ground condition would rather be difficult than in space condition.

Contact Simulation of Stopper

- Contact simulation of stopper
- Contact point on divided elastic link → Simulation accuracy problem



- Determination of contact parameters
- Convergence of solutions
- From Impact Function to Contact Definition
 - Reduction of simulation time
 - Difficulty of signal processing
 - Less intuitive understandable animation

How to simulate beam dynamics

Apply ADAMS/Flex ?

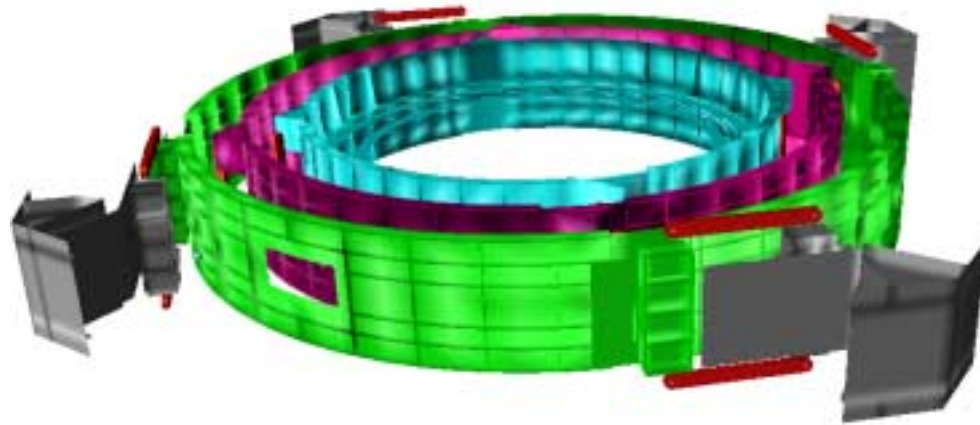
- Better simulation accuracy
- Equivalent simulation time ?
- Less quality of animation

Further functional
enhancement is needed.

Effects of Flexibility on CR Dynamics

- Weight saving is an important issue for Space Equipment Design, however it causes low rigidity of structures.

Treat structural members as elastic bodies
by ADAMS/Flex



- Structural simulation by ADAMS/Flex = Experience of structural simulation + Understanding of CR structures itself
- Good accuracy for frequency domain simulation (Better than structural simulation only)



Evaluation by time history simulation

Conclusions

- ADAMS could simulate the complex CR dynamic behavior.
- ADAMS was appraised as a strong tool for CR development.
- ADAMS animation enabled us to understand a mechanism of the newly developing complex machinery.
- ADAMS could deal with structure and control in a same framework.

Future Works

- Development of integrated CR/CAM/ISS models by ADAMS
- Timer history analysis of elastic rotor by ADAMS/Flex
- Integrated simulation with structure and control by ADAMS/Controls