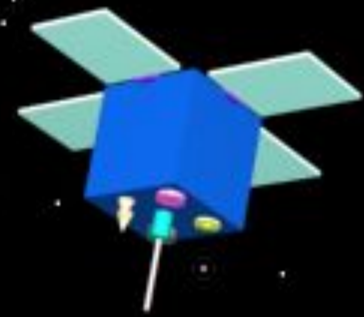


Effect of Structure Flexibility on Attitude Dynamics of Modernizated Microsatellite

Overview

- Research Objectives and Tasks
- Micro satellite Configuration
- Reference frames
- Mathematical Models of flexible space structures
- Major Findings and Results
- Recommendations for Future Research

Research Objectives and Tasks

The major objective of this research is to study the effect of structure flexibility on attitude behavior (Euler angles and angular velocities) of micro satellites and the degree of such effect

Research Objectives and Tasks

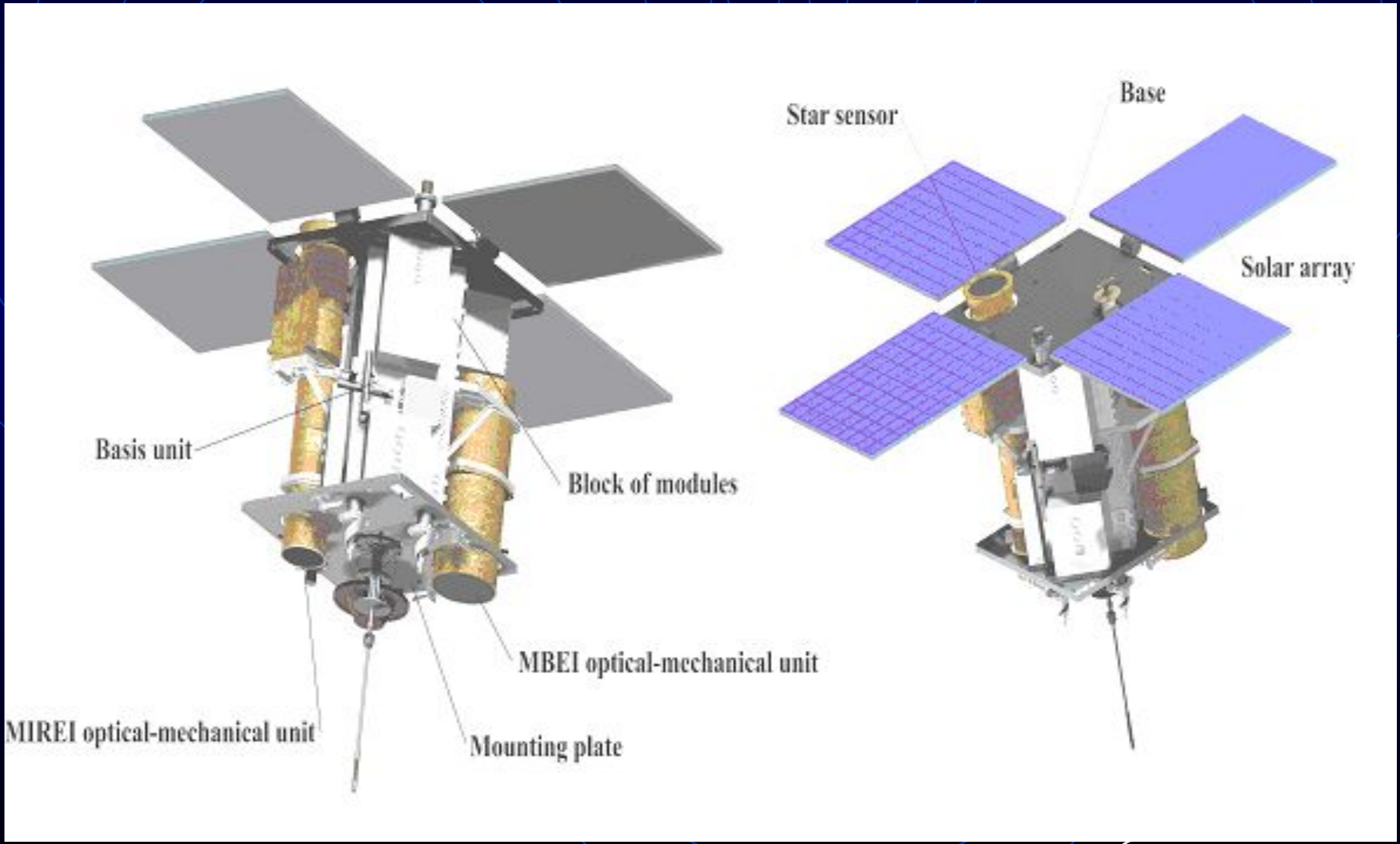
- The research objectives and tasks of this study are as follows :
  - Develop mathematical models of flexible space structures
  - Determine the attitude accuracy

Micro Satellite Configuration

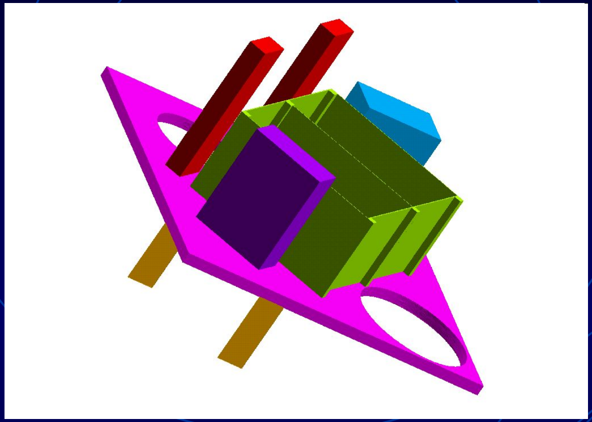
- The construction of micro satellite can consist of main parts: base plate, mounting plate, walls, blocks and the payloads.

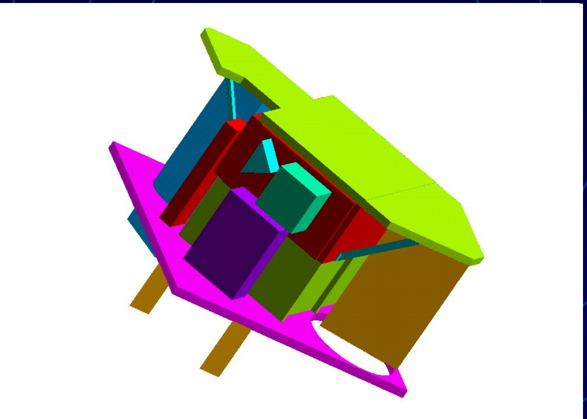
- Each part and subpart of this construction will be replaced by the equivalent solid mass and moment of inertia with respect to the real construction.

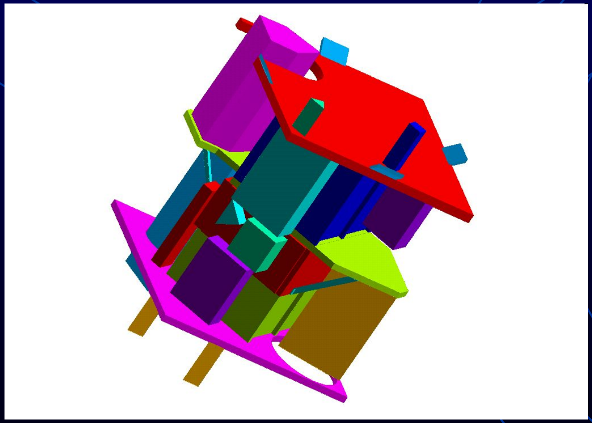
Micro Satellite Configuration

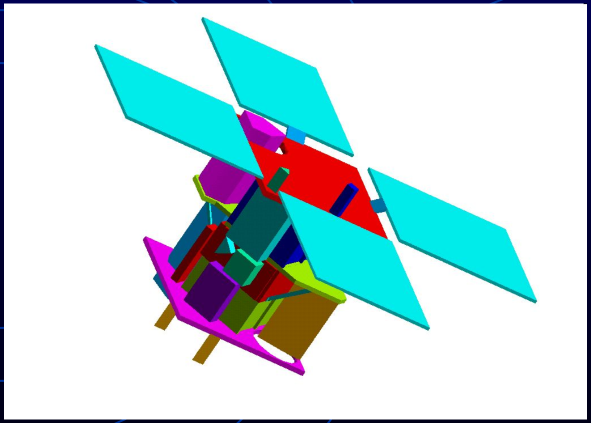


Micro Satellite Configuration



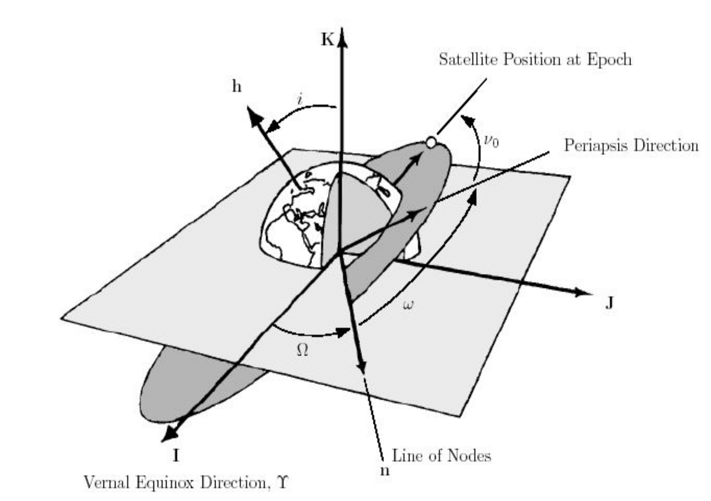


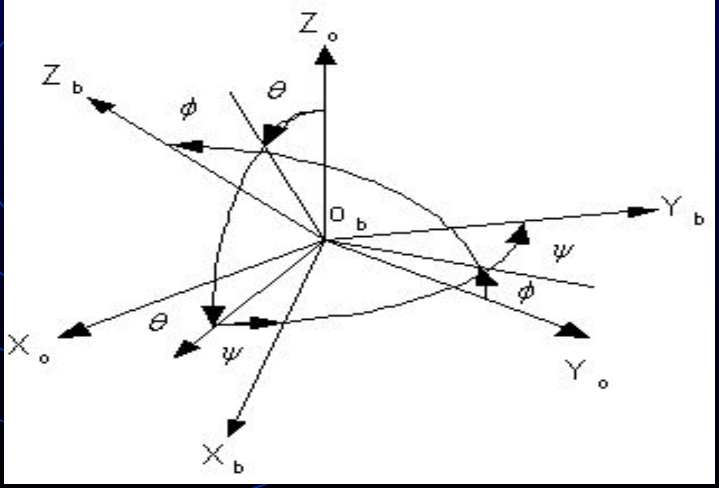




Reference Frames

- Inertial coordinate system (ICS)
- Orbital coordinate system (OCS)
- Design coordinate system (DCS)
- Body axes system (BAS)





Mathematical Models of Flexible Space Structures

- A mathematical model of the satellite takes into account flexible body components (solar panels, antennas, booms etc…);

- This kind of modelling consists of two parts one related to rigid body motion and the other to flexible body motion.

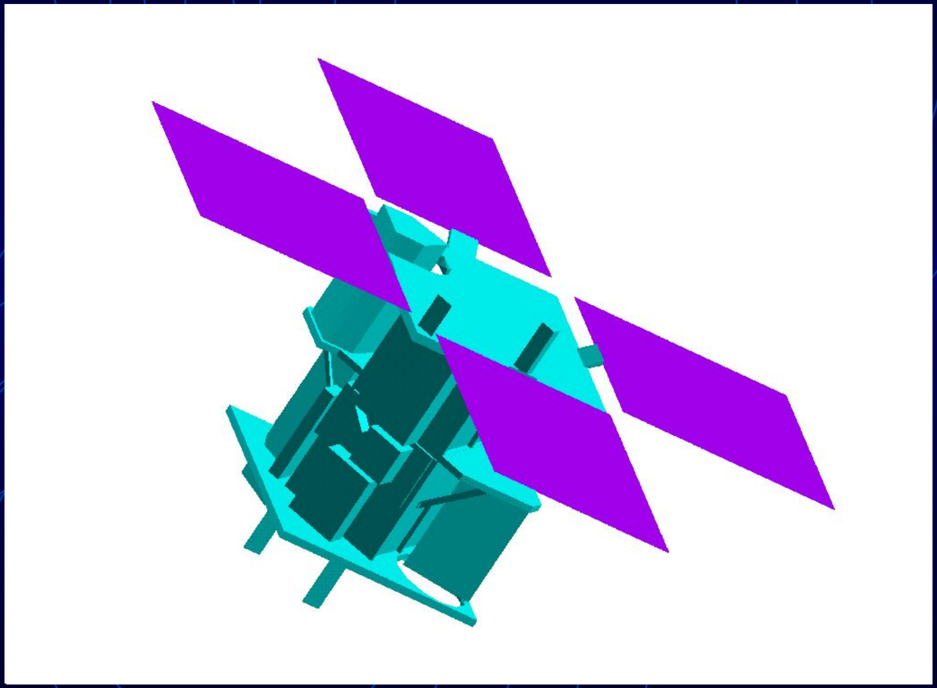
Mathematical Models Of Flexible Space Structures

- Two kind of software will be used ANSYS and MATLAB;
  - ANSYS software will be used to calculate the modal analysis (natural frequencies and mode shapes) ;
  - MATLAB software will be used to integrate the system of equations .

Mathematical Models Of Flexible Space Structures

Finite Element Model :

- SHELL 99
- SOLID 92



Mathematical Models Of Flexible Space Structures

- The dynamic equations of motion around center of mass taken into account the elastic oscillations of a housing of satellite and solar panels can be written in the following form :

$$\bar{\bar{J}} \cdot \dot{\bar{\varpi}} + \bar{\varpi} \times \bar{\bar{J}} \cdot \bar{\varpi} + \sum_{i=1}^{n} \left(\bar{G}_{1i} \cdot \ddot{q}_i + \bar{G}_{2i} \cdot \ddot{p}_i + \bar{G}_{3i} \cdot \ddot{r}_i \right) +$$

$$+ \bar{\varpi} \times \sum_{i=1}^{n} \left(\bar{G}_{1i} \cdot \dot{q}_i + \bar{G}_{2i} \cdot \dot{p}_i + \bar{G}_{3i} \cdot \dot{r}_i \right) = \bar{M}_s,$$

$$\bar{G}_{1i} \cdot \dot{\bar{\varpi}} + m \cdot \ddot{q}_i + \varepsilon_i \cdot \dot{q}_i + c_i \cdot q_i = 0,$$

$$\bar{G}_{2i} \cdot \dot{\bar{\varpi}} + m \cdot \ddot{p}_i + \varepsilon_i \cdot \dot{p}_i + c_i \cdot p_i = 0,$$

$$\bar{G}_{3i} \cdot \dot{\bar{\varpi}} + m \cdot \ddot{r}_i + \varepsilon_i \cdot \dot{r}_i + c_i \cdot r_i = 0, \qquad i = 1,\ 2,\ \ldots,\ n$$

Mathematical Models Of Flexible Space Structures

The calculation of flexible modes elements (Gαi) are usually determined by the following way in BAS :

$$\overline{G}_{\alpha i}^{(b)} = \int_m \overline{\rho}^{(b)} \times \overline{U}_{\alpha i}^{(b)} dm, \qquad \alpha = 1,\ 2,\ 3$$

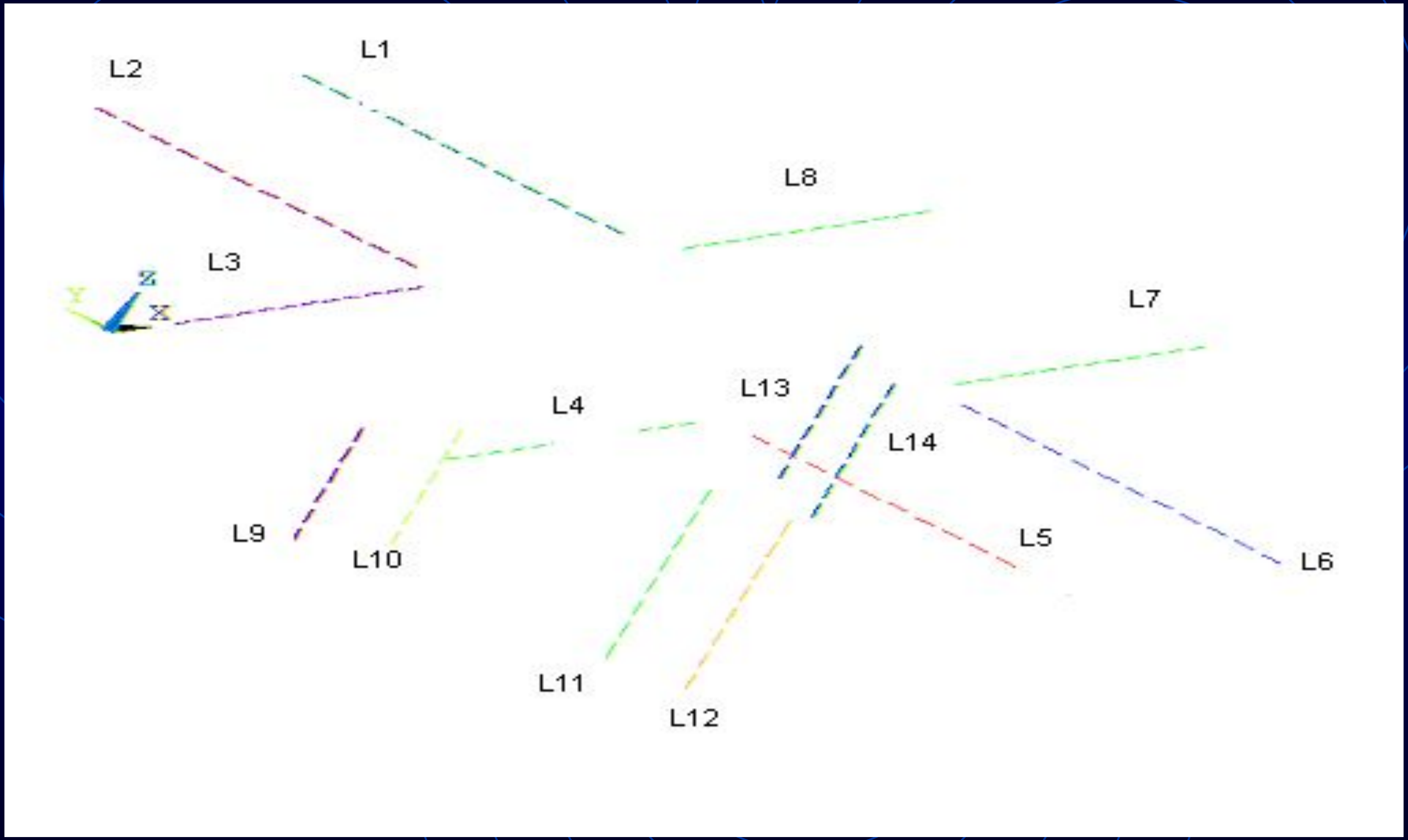
$$\overline{U}_{1i}^{(c)} = \left| U_{xi},\ 0,\ 0 \right|^T; \qquad \overline{U}_{2i}^{(c)} = \left| 0,\ U_{yi},\ 0 \right|^T; \qquad \overline{U}_{3i}^{(c)} = \left| 0,\ 0,\ U_{zi} \right|^T$$

$$\overline{G}_{\alpha i}^{(c)} = \sum_{j=1}^{k} M_j \int_0^1 \overline{\rho}_j^{(c)} \times \overline{U}_{\alpha ij}^{(c)} ds_j$$

ρ_b : is a radius vector that connects satellite COM to any arbitrary point of the satellite construction;

$U_{\alpha i}$: is a vector to describe the mode shape.

Mathematical Models Of Flexible Space Structures



Lines of micro satellite used for representing flexible elements.

Mathematical Models Of Flexible Space Structures

The satellite kinematics equations will be in the following form :

$$\begin{vmatrix} \dot{\varphi} \\ \dot{\vartheta} \\ \dot{\psi} \end{vmatrix} = \frac{1}{\operatorname{Cos}\varphi} \begin{vmatrix} \sin\psi & \cos\psi & 0 \\ \cos\psi\cos(\varphi) & -\sin(\psi)\cos(\varphi) & 0 \\ \sin(\psi)\sin(\varphi) & \cos(\psi)\sin(\varphi) & \cos(\varphi) \end{vmatrix} \cdot \overline{\omega}_{bo},$$

ω_{bo} : is the satellite body angular velocity with respect to the OCS;

θ, φ, ψ : are EULER angles pitch, roll and yaw respectively.

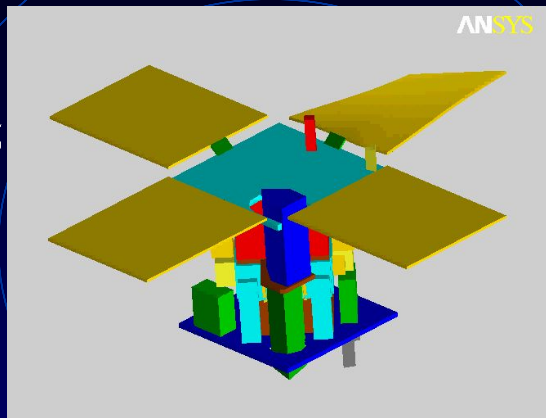
Finding and Major Results

- Average values for frequencies (f_i) for the first six tones groups are equal to: 14; 26.7; 65.5; 86.9; 90.2; 113 Hz respectively;
- It is noted that the first five tones groups is related to the solar panels of the satellite and at the group tone number six is for the housing.

Finding and Major Results

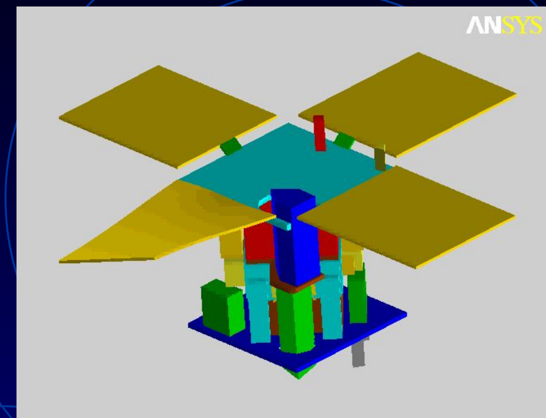
26.85

HZ



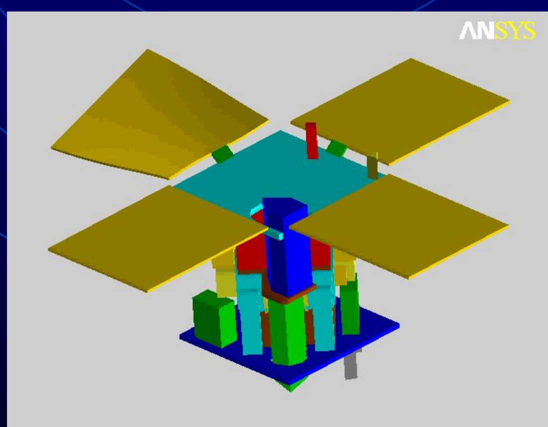
26.99

HZ



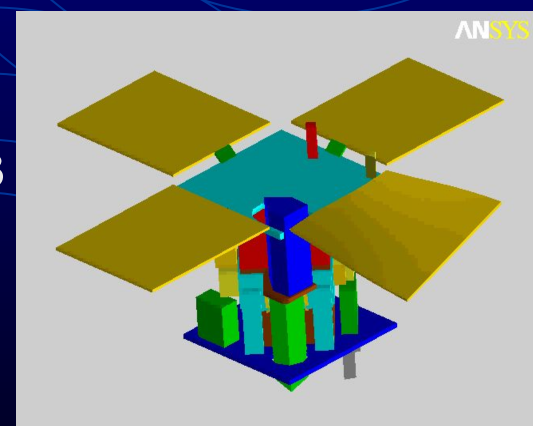
27.02

HZ



27.03

Hz

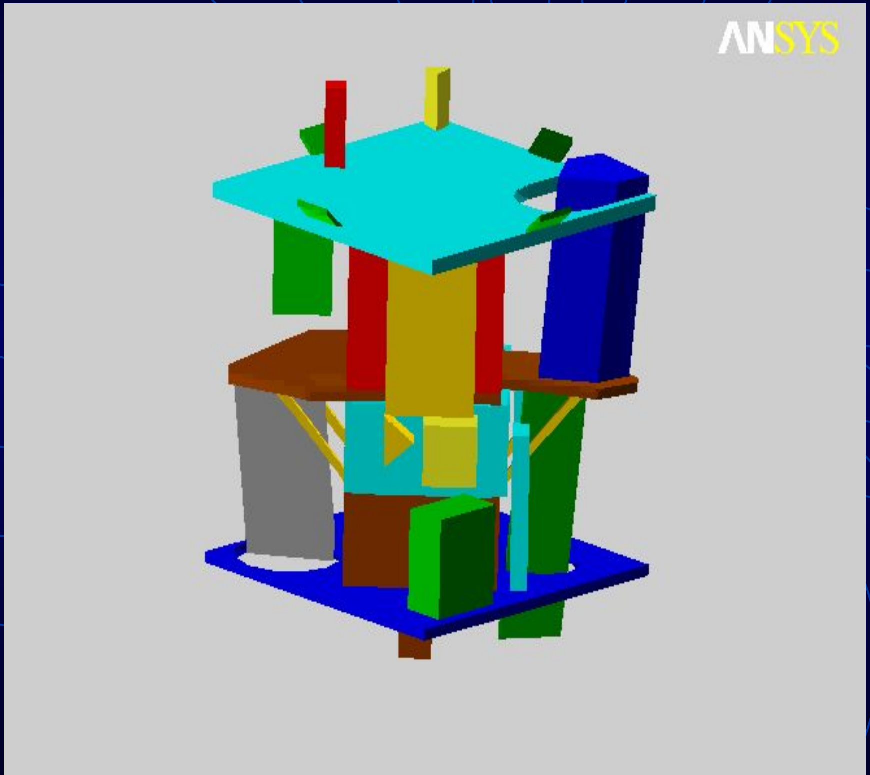


Micro satellite solar panels 2nd tones groups.

Finding and Major Results

113.36

HZ



Micro satellite housing 1st tone.

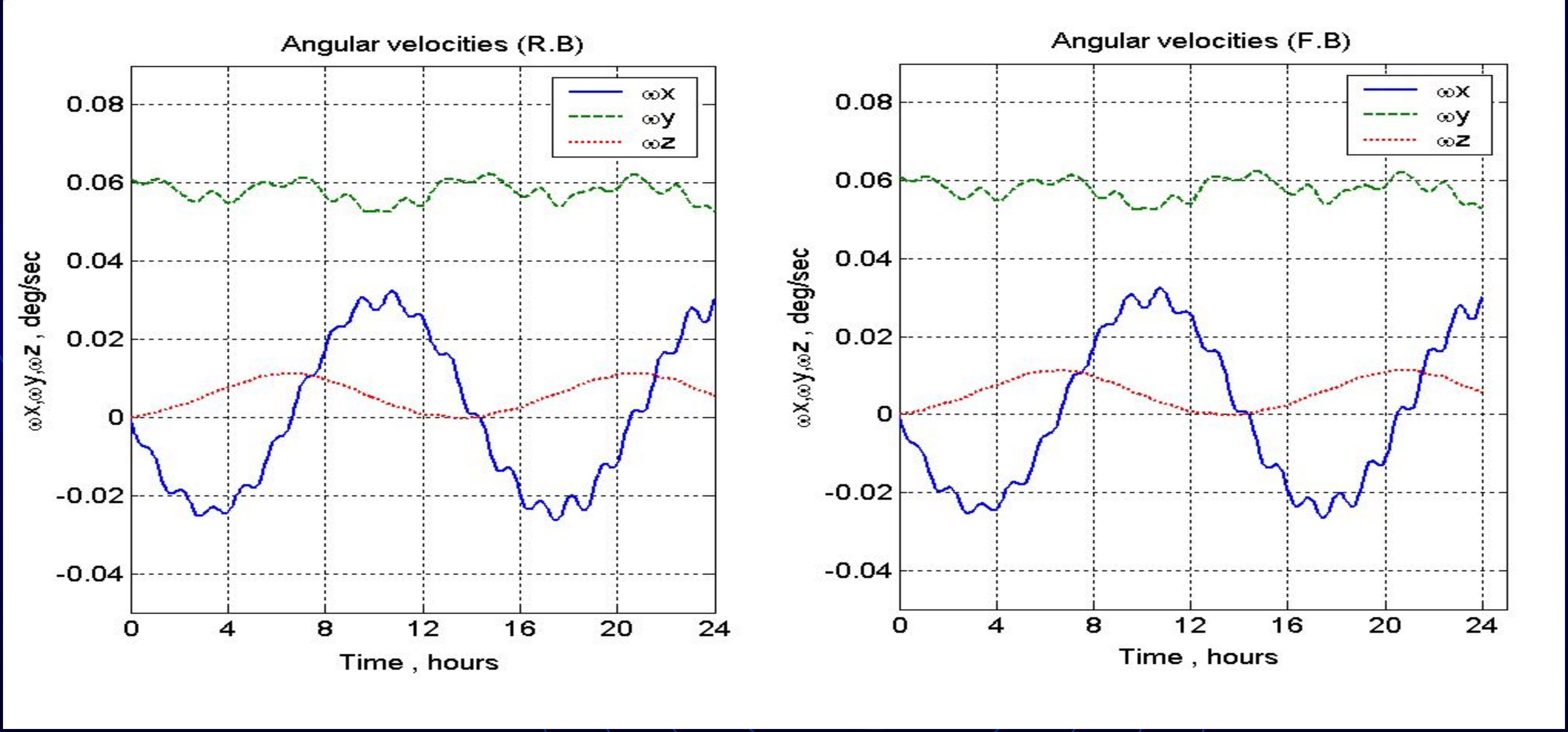
Finding and Major Results

- The simulations of satellite dynamics (Euler angles and angular velocities) is carried out using MATLAB software on the following two cases :
  - On the satellite as a RIGID BODY
  - On the satellite as a FLEXIBLE BODY (taking into account vibration modes of the satellite)

Finding and Major Results

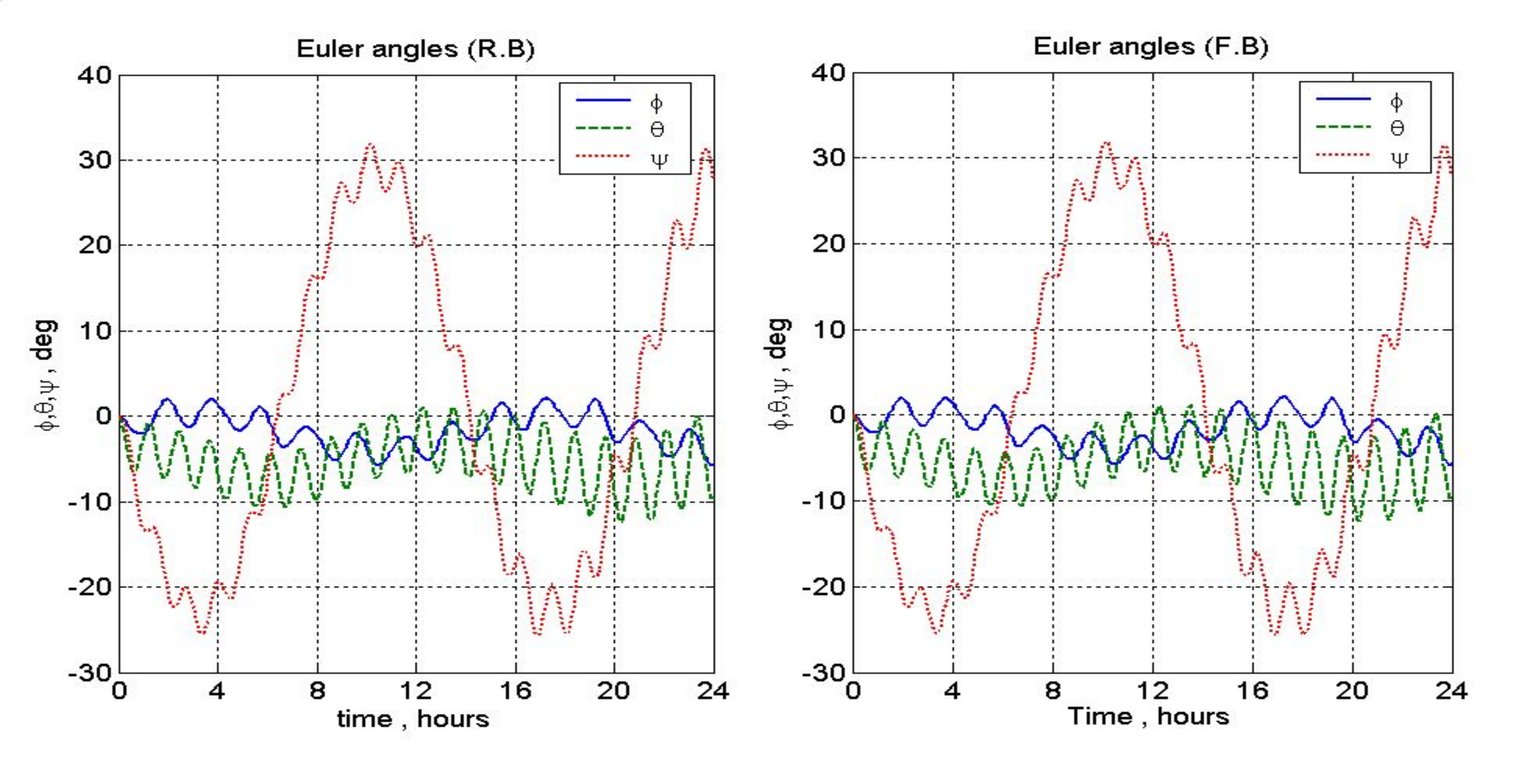
- On both the above situations the gravitational moment is the only external moment
- Result of simulation are shown in the following figures. From this results it is noted that their is unobserved different between rigid and flexible body simulations

Finding and Major Results



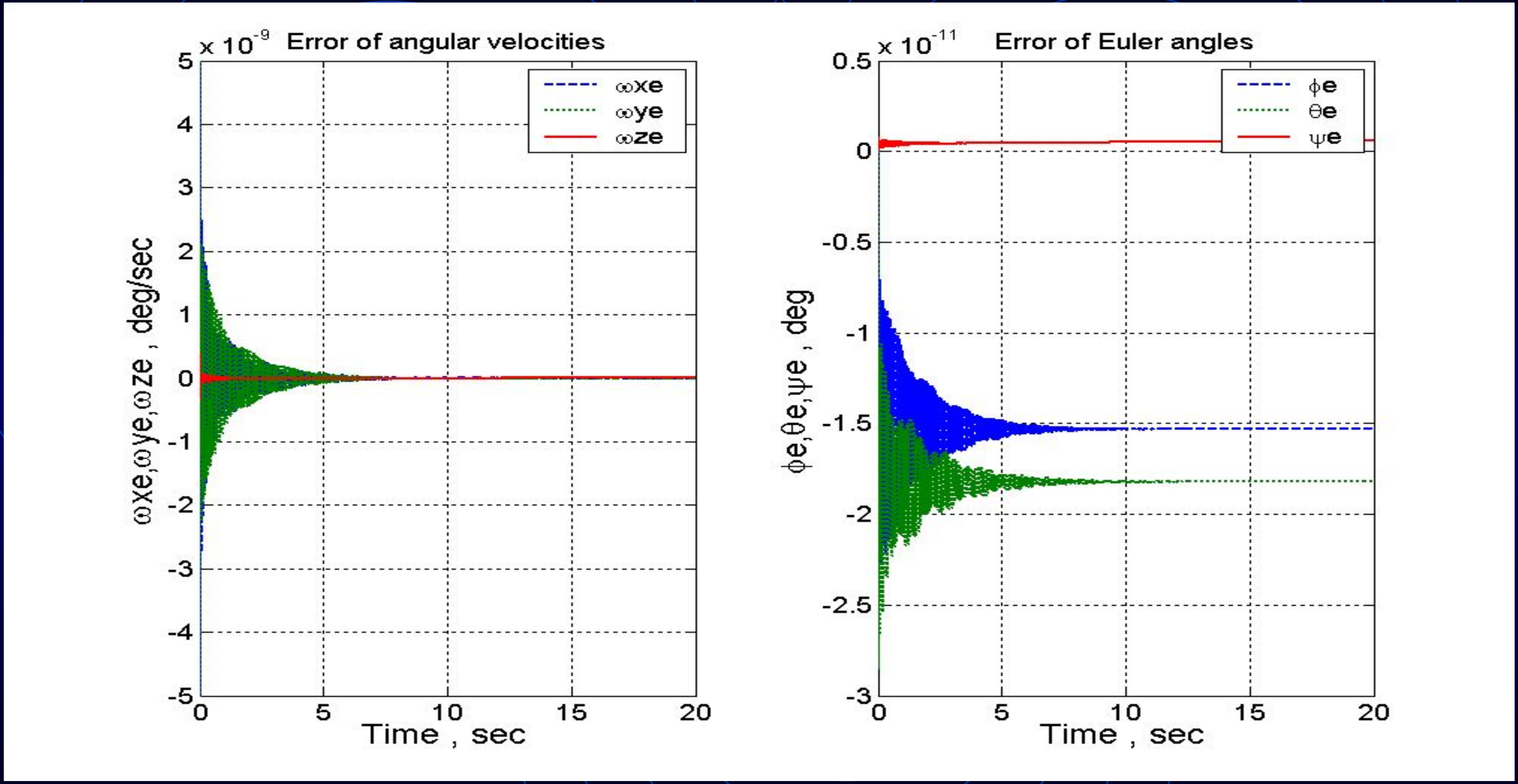
Simulation of attitude dynamics (angular velocities) with and without flexible moments

Finding and Major Results



Simulation of attitude dynamics (Euler angles) with and without flexible moments

Finding and Major Results



Error of attitude dynamics (Euler angles and angular velocities) due to flexible moment in 20 sec

Recommendations For Future Research

- Recommendations for designers and engineers concerning the satellite structure flexibility necessities within the framework of the following :
  - Resolution requirements of the payload
  - Satellite attitude accuracy requirements
  - Satellite structural layout diagram