Self-Gravity Analysis and Visualization Tool for LISA

Avi Gopstein[1], William Haile[1], Stephen Merkowitz[2]

1 – Swales Aerospace: Beltsville, Maryland USA

2 – NASA Goddard Space Flight Center: Greenbelt, Maryland USA

Self-gravity noise due to sciencecraft distortion and motion is expected to be a significant contributor to the LISA acceleration noise budge. To minimize these effects, the gravitational field at each proof mass must be kept as small, flat, and constant as possible. Most likely it will not be possible to directly verify that the LISA sciencecraft meets these requirements by measurements; they must be verified by models. The LISA Integrated Modeling team developed a new self-gravity tool that calculates the gravitational forces, moments, and gradients on the proof masses and creates a color coded map of the component contributions to the self-gravitational field. The color mapping provides an easily recognized and intuitive interface for determining the self-gravitational hot-spots of a spacecraft design. Self-gravitational color maps can be generated as true representations of the steady-state, or as an approximation of the variability through computation of the difference values across multiple physical states. We present here an overview of the tool and the latest self-gravity results calculated using a recent design of LISA.

Workflow:

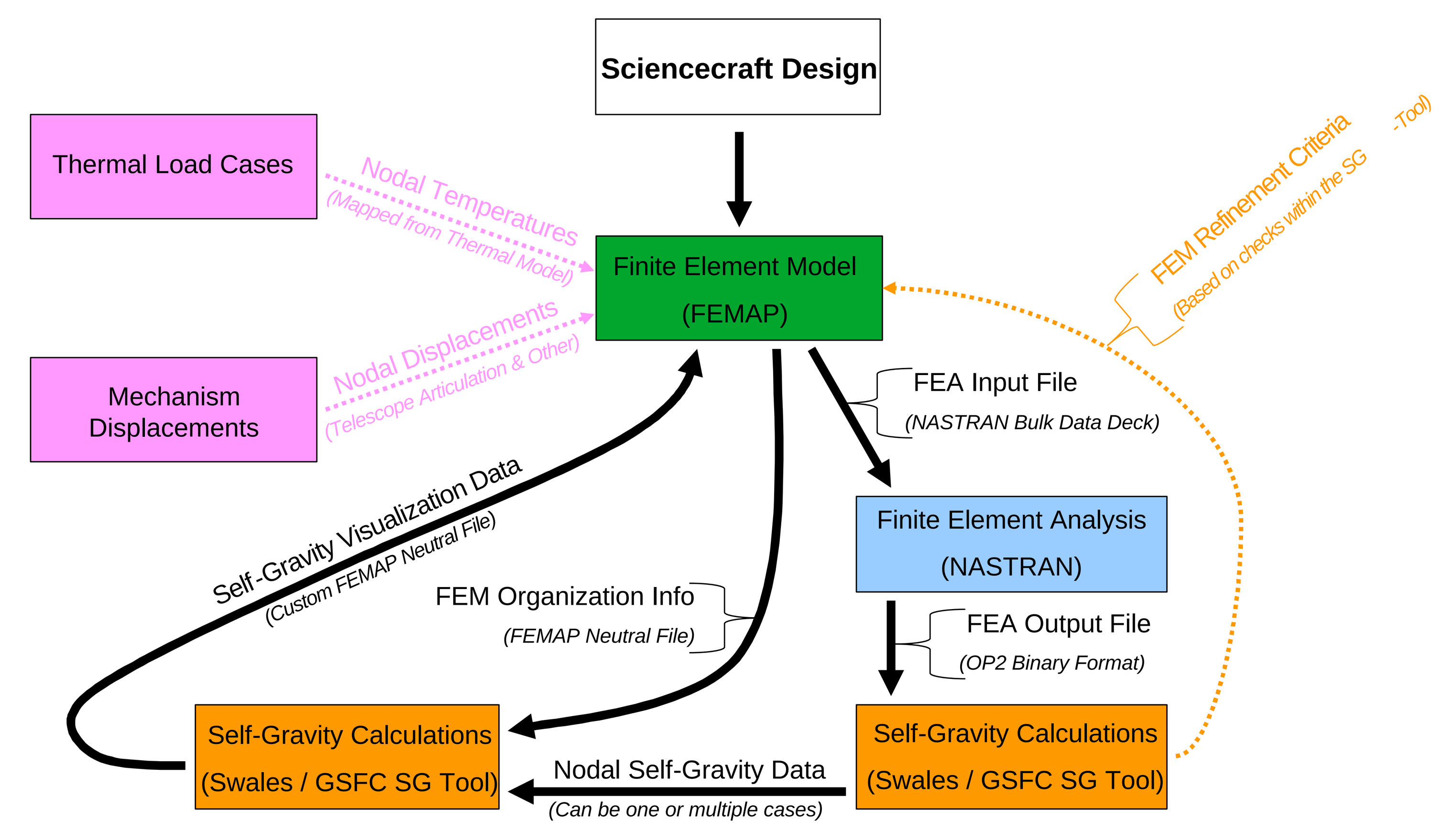


Figure 1 – Workflow for the Visualization of LISA Self-Gravity: The solid lines indicate required elements of the workflow, whereas the dotted lines represent optional processes. Both the Thermal Load Cases and Mechanism Displacements result in nodal displacements that are not required for analysis, but can be incorporated into the workflow when multiple thermal load cases or mechanical configurations are considered and relative changes in the Self-Gravity field are to be considered

The workflow chart at left shows the path of information and data, along with the associated analysis tools, required to generate color plots for visualization of the Self-Gravitational field component contributions due to sciencecraft structures:

- From the sciencecraft design, a structural Finite Element Model (FEM) is created using FEMAP, and the required input files are generated for the Finite Element Analysis and Self-Gravity Calculations.
  - If either **Thermal Load Cases** along with the resulting structural deformations or **Mechanism Displacements** due to movement of sciencecraft components are to be included in the analysis, these criterion are incorporated in the **FEMAP Model** prior to generating the **FEA Input File.**
- NASTRAN is used to analyze the FEM and generate the required rigid body vector input files for the SG Tool.
- The SG Tool uses the NASTRAN output and calculates the contribution of each nodal mass to Self-Gravitational field at the Proof Mass. 42 unique Self-Gravity terms are calculated for each node.
  - The **SG Tool** also performs numerous checks on FEM geometry. Should the internodal spacing be too large for accurate computation of the SG terms, the **FEMAP Model** must be modified.
- The SG Tool combines the FEM Organization Information and previously calculated Nodal Self-Gravity Data to calculate the sciencecraft structural contributions to the Self-Gravitational field at the Proof Mass. The results are written to a file that is imported into FEMAP for color mapping.
  - When deformation cases are considered, the SG Tool first calculates the baseline Self-Gravity field, and the color maps generated for each subsequent configuration/deformation case are of the *difference* between the case and baseline Self-Gravitational fields.

Finite Element Model: The latest version of the LISA TRIP FEM was used for this study

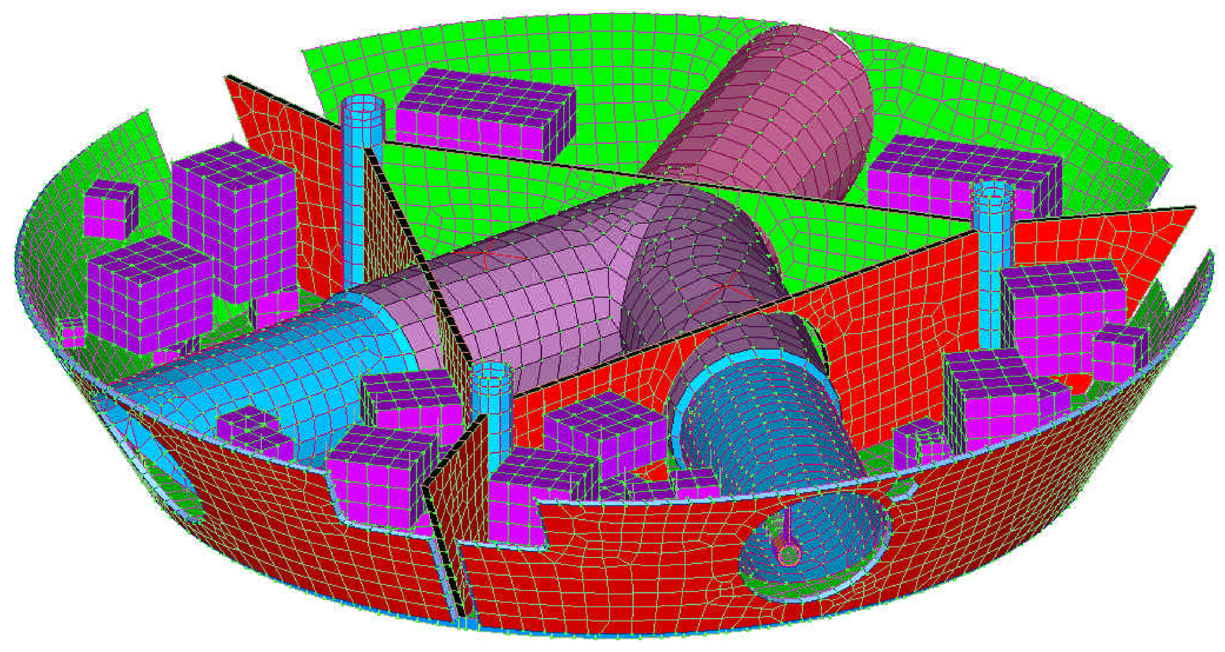


Figure 2 – LISA TRIP FEM: The TRIP configuration FEM used for this study is shown here. The top plate, solar panels and thermal shield have been hidden to reveal the internal sciencecraft component structure, but were included in the Self-Gravity calculations. The model contains 55,053 elements and 43,202 nodes organized within FEMAP.

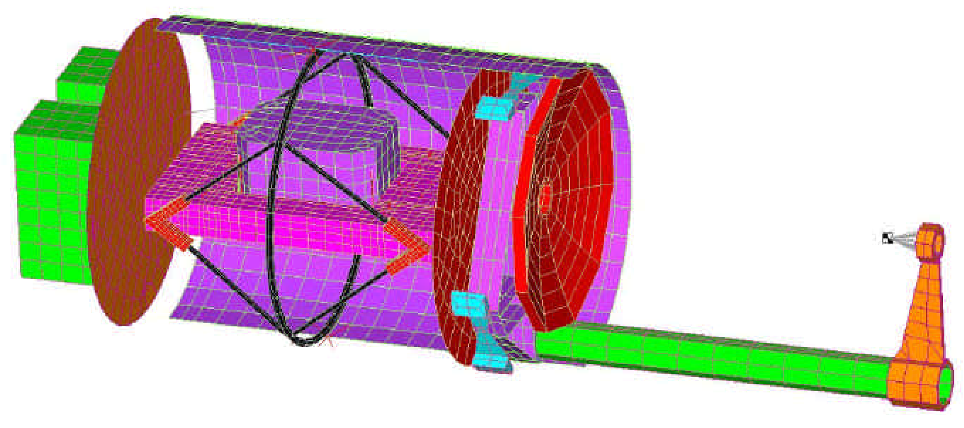
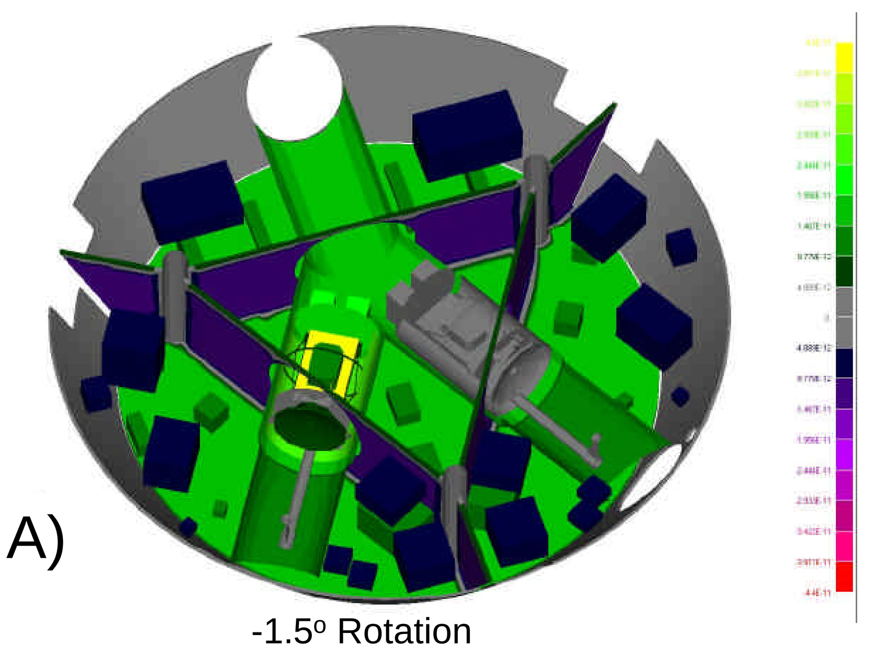


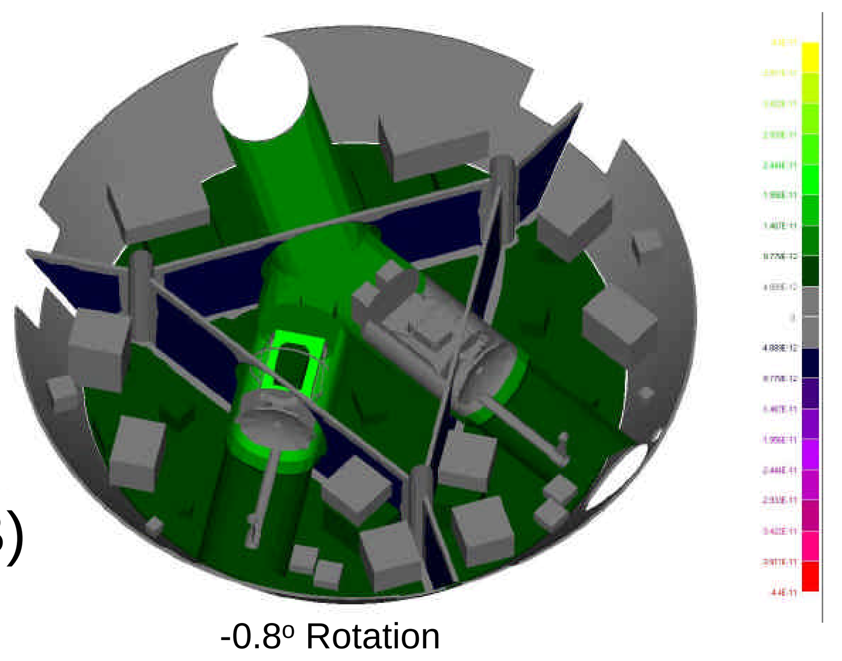
Figure 3 – Detail of Telescope Assembly: One of two telescope assemblies contained within the Y-tube and Telescope Shroud of the LISA TRIP FEM. A portion of the thermal shield has been removed to reveal the optical bench and other detail contained within the Telescope Assemblies. The +Y assembly was rotated about multiple pivot point and the Self-Gravity field differential was calculated across multiple configurations. Not visible are the Proof Mass and Proof Mass housing, which are contained inside the Proof Mass vacuum enclosure.

- The +Y Telescope assembly was rotated through 7 different articulation configurations:
  - Neutral (0º rotation)
  - +/- 0.4º rotation
  - +/- 0.8º rotation
  - +/- 1.5º rotation
- Each articulation configuration was analyzed for three different pivot points about which the angular rotation was centered:
  - The center of the Proof Mass
  - The center of mass of the telescope assembly
  - A point at the front of the optical bench located 175mm from the center of the Proof Mass

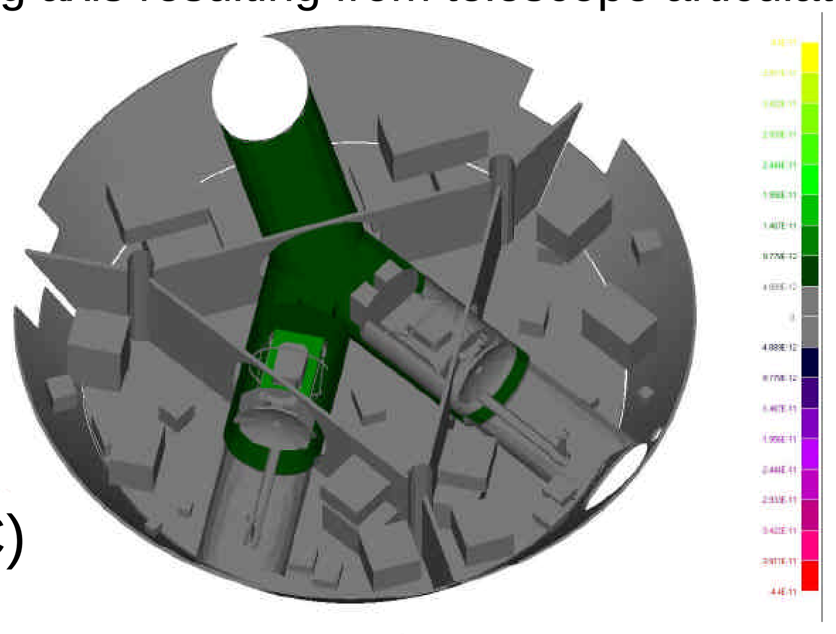
Articulation Study Results: The Self-Gravitational field difference (?F) Along the sensing axis resulting from telescope articulation



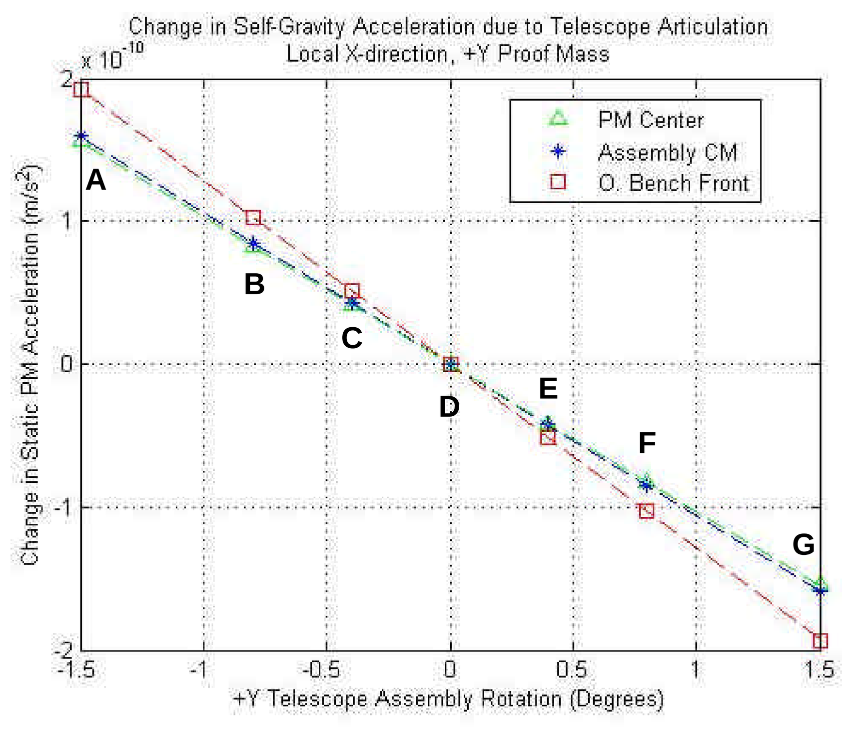
A) -1.5º Rotation

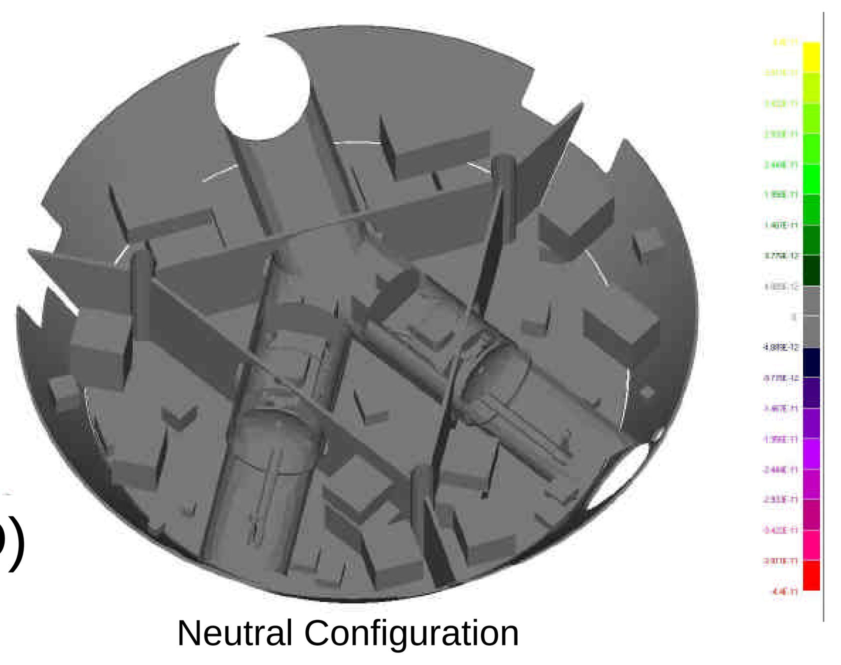


B) -0.8º Rotation

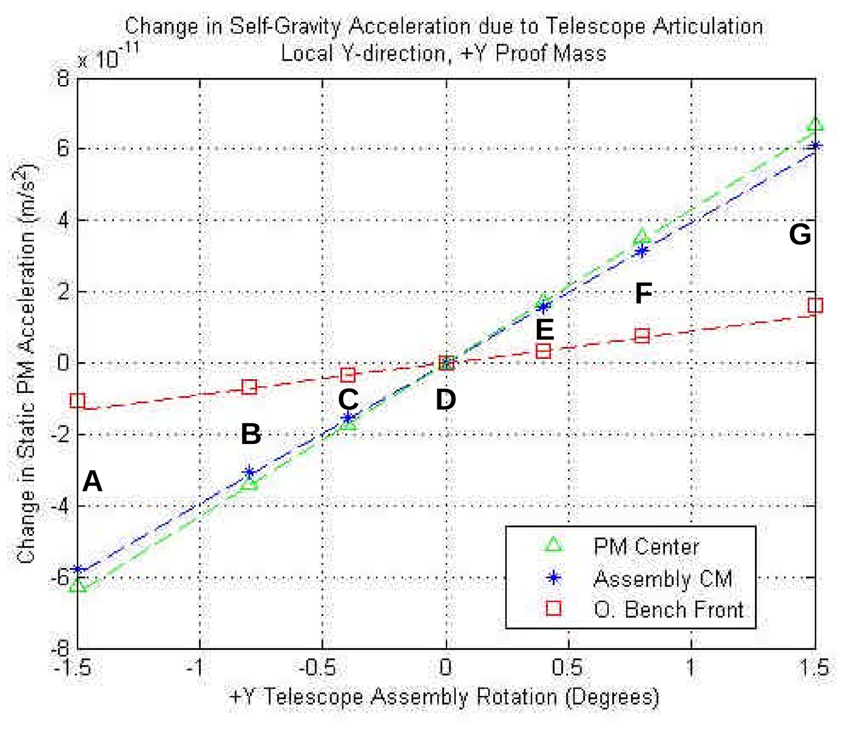


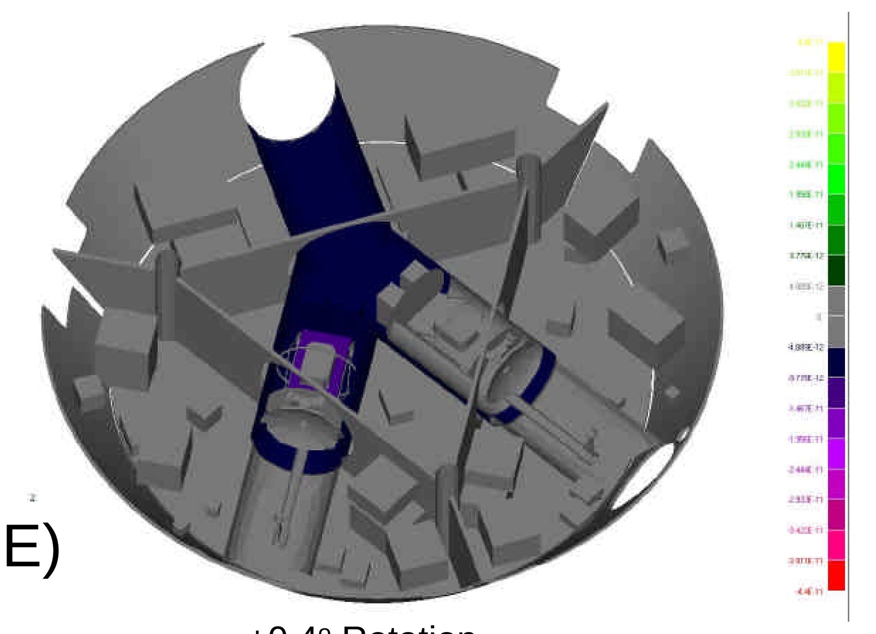
C) -0.4º Rotation



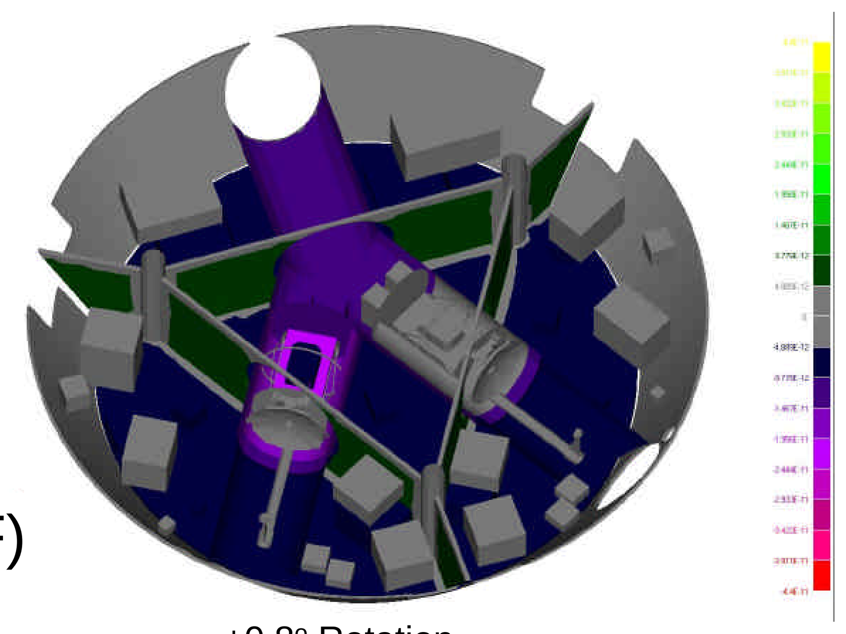


D) Neutral Configuration

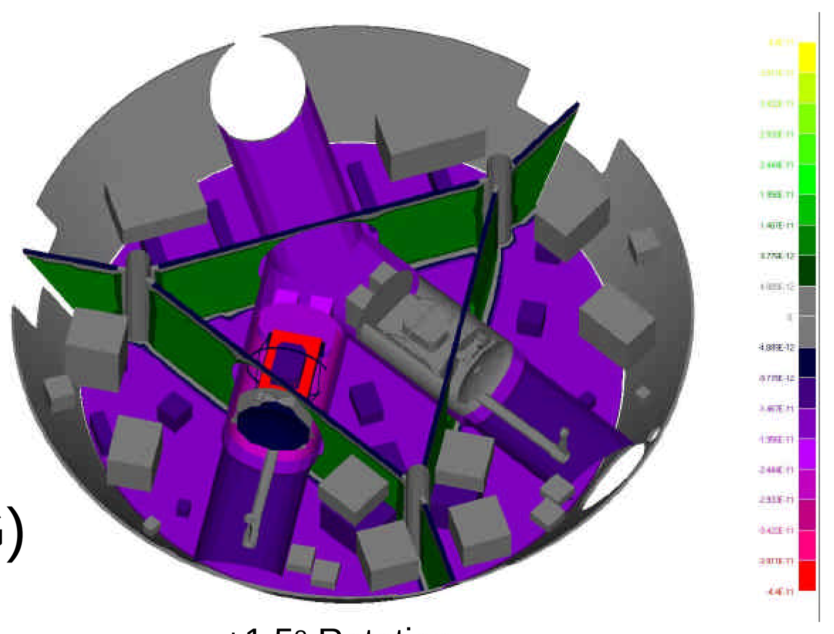




E) +0.4º Rotation



F) +0.8º Rotation



G) +1.5º Rotation