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IASF CALIBRATION MGSE
DESIGN, ANALYSIS AND TEST REPORT

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01	20/07/2005		First issue	

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1. INTRODUCTION

The AGILE IASF Calibration Mechanical Ground Support Equipment (MGSE) consists of the mechanical items that CNR IASF Sezione di Bologna have to procure in order to support the Calibration activities to be performed on the AGILE Integrated Payload (IPL) at beam facilities.

Aim of this document is to present the results of the design and analysis activities which have been carried out by Studio Zocca in the framework of the Work Package WP C-IM-01.

The analysis have been performed on the MGSE designed by IASF Bologna in order to verify from the engineering point of view the compliance of the design with the specifications stated in AD[1].

The final version of the construction drawings is listed in Section 3.

The detailed design of MGSE axis is presented in Section 4, and the results of the FEM analysis are provided in Section 5. Section 6 and 7 provide details on the lifting and levelling provisions.

Section 8 presents the results of the tests which have been carried out at IASF Sezione di Bologna in order to verify the actual performances against the results of the FEM analysis.

The resulting MGSE is shown in Figure 1-1. It operates as a numerical control machine, and its assembly is divided in three subgroups:

1) MGSE horizontal motion group

2) MGSE vertical motion group

3) MGSE vertical rotation group

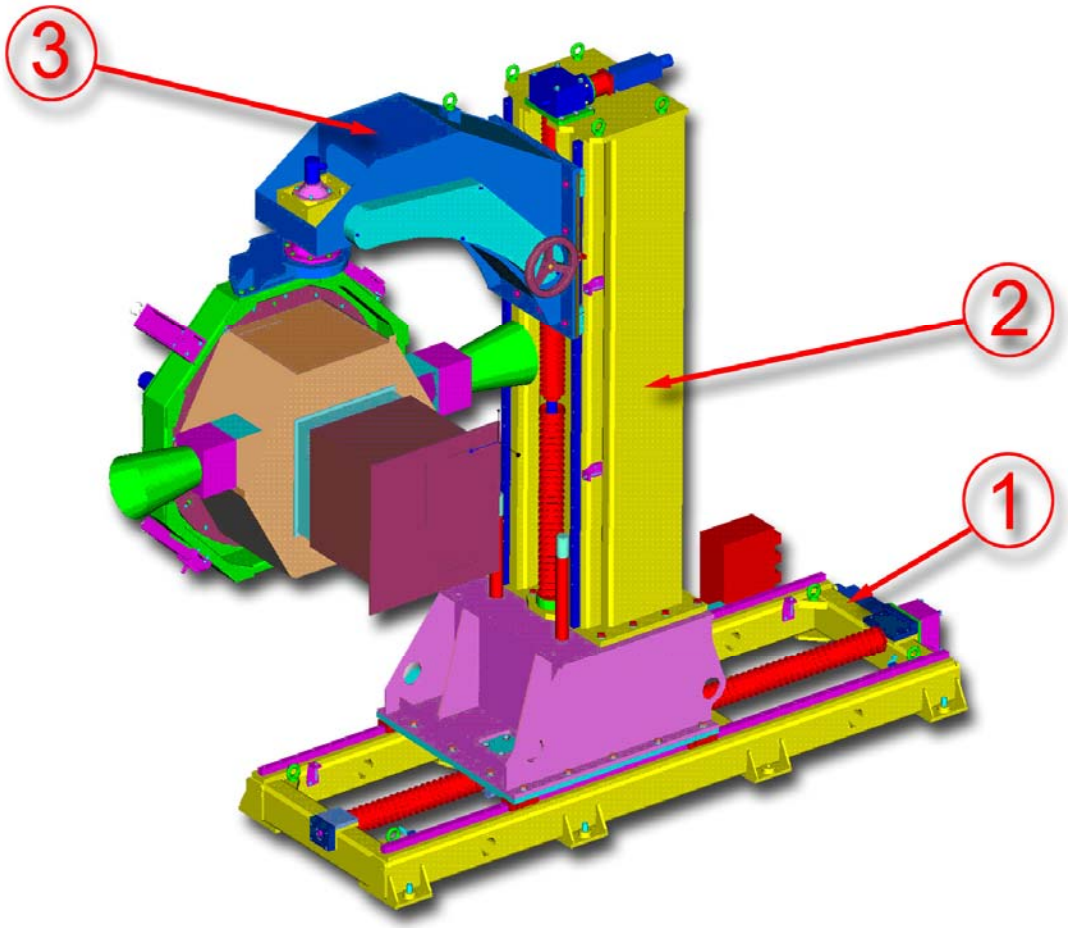


Figure 1-1 Isometric view of the Calibration MGSE with the AGILE IPL.

2. APPLICABLE AND REFERENCE DOCUMENTS

2.2. Applicable Documents

AD [1] AGILE-ITE-SR-006 “AGILE Integrated Payload IASF MGSE Requirement Specifications”, Issue 1, November 2003

2.3. Reference Documents

RD [1] AGILE-ITE-RE-006 “AGILE Payload Calibration MGSE Design Report”, Issue 1, November 2003

3. MGSE CONSTRUCTION DRAWINGS

MGSE (assembly)	Drawing
MGSE orizzontal motion	PMGSE-C-IM-01-A1
MGSE vertical motion	PMGSE-C-IM-01-A2
Complessivo MGSE vista Iso anteriore	PMGSE-C-IM-01-A3
Complessivo MGSE vista Iso posteriore	PMGSE-C-IM-01-A4
Complessivo MGSE vista frontale	PMGSE-C-IM-01-A5
Complessivo MGSE vista Iso generale	PMGSE-C-IM-01-A6
Complessivo MGSE vista Baricentro	PMGSE-C-IM-01-A7

MGSE (horizontal motion group)	Drawing
Bancale	PMGSE-C-IMA-01-A
Rotaia Tx	PMGSE-C-IMA-02-A
Pattino Tx	PMGSE-C-IMA-03-A
Piastra carrello Tx	PMGSE-C-IMA-04-A
Supporto chiocciola Tx	PMGSE-C-IMA-05-A
Chiocciola Tx	PMGSE-C-IMA-06-A
Martinetto orizzontale Tx	PMGSE-C-IMA-07-A
Distanziale martinetto Tx	PMGSE-C-IMA-08-A
Riduttore epicicloidale Tx	PMGSE-C-IMA-09-A
Motore Tx	PMGSE-C-IMA-10-A
Supporto barra Tx	PMGSE-C-IMA-11-A
Staffa martinetto Tx	PMGSE-C-IMA-12-A
Piastra di chiusura	PMGSE-C-IMA-13-A
Flangia interfaccia riduttore epic. – martinetto Tx	PMGSE-C-IMA-14-A
Golfare ad occhio circolare M16	PMGSE-C-IMA-15-A
Supporto interruttore limite Sw. Tx	PMGSE-C-IMA-16-A
Tastatore micro Dx asse Tx	PMGSE-C-IMA-17-A
Interruttore di prossimità	PMGSE-C-IMA-18-A
Tastatore fine corsa Tx	PMGSE-C-IMA-19-A
Supporto micro Sx asseTx	PMGSE-C-IMA-20-A
Tastatore micro Sx asse Tx	PMGSE-C-IMA-21-A
Prigioniero martinetto Tx	PMGSE-C-IMA-22-A
Switch fine corsa Dx asse Tx	PMGSE-C-IMA-23-A
Soffietto “D” Tx	PMGSE-C-IMA-24-A
Soffietto”C” Tx	PMGSE-C-IMA-25-A
Tappo	PMGSE-C-IMA-26-A
Battente fine corsa Dx	PMGSE-C-IMA-27-A
Battente fine corsa Sx	PMGSE-C-IMA-28-A
Dischetto per livellamento	PMGSE-C-IMA-29-A
Anello bloccaggio soffietto	PMGSE-C-IMA-30-A
Staffa catena porta cavi	PMGSE-C-IMA-31-A
Supporto ingrassatore	PMGSE-C-IMA-32-A
Tubino ingrassatore chiocciola Tx	PMGSE-C-IMA-33-A
Barra attacco cassetta	PMGSE-C-IMA-34-A
Staffa di bloccaggio asse Tx (Trasporto)	PMGSE-C-IMA-35-A

MGSE (Vertical motion group)	Drawing
Basamento	PMGSE-C-IMB-01-A
Colonna	PMGSE-C-IMB-02-A
Rotaia Tz	PMGSE-C-IMB-03-A
Pattino Tz	PMGSE-C-IMB-04-A
Piastra interfaccia trave	PMGSE-C-IMB-05-A
Supporto chiocciola Tz	PMGSE-C-IMB-06-A
Martinetto verticale Tz	PMGSE-C-IMB-07-A
Distanziale martinetto Tz	PMGSE-C-IMB-08-A
Chiocciola Tz	PMGSE-C-IMB-09-A
Riduttore epicicloidale Tz	PMGSE-C-IMB-10-A
Motore Tz	PMGSE-C-IMB-11-A
Supporto micro asse Tz	PMGSE-C-IMB-12-A
Tastatore micro asse Tz	PMGSE-C-IMB-13-A
Interruttore di prossimità	PMGSE-C-IMB-14-A
Supporto cuscinetto martinetto Tz	PMGSE-C-IMB-15-A
Supporto tastatore	PMGSE-C-IMB-16-A
Supporto micro superiore Tz	PMGSE-C-IMB-17-A
Micro fine corsa superiore Tz	PMGSE-C-IMB-18-A
Flangia interfaccia riduttore epic.-Martinetto	PMGSE-C-IMB-19-A
Prigioniero martinetto Tz	PMGSE-C-IMB-20-A
Soffietto superiore Tz	PMGSE-C-IMB-21-A
Soffietto inferiore Tz	PMGSE-C-IMB-22-A
Battente fine corsa	PMGSE-C-IMB-23-A
Prolunga di battuta	PMGSE-C-IMB-24-A
Supporto attacco visore	PMGSE-C-IMB-25-A
Ralla	PMGSE-C-IMB-26-A
Braccio mobile	PMGSE-C-IMB-27-A
Attacco visualizzatore	PMGSE-C-IMB-28-A
Supporto catena porta cavi	PMGSE-C-IMB-29-A
Battente superiore fine corsa Tz	PMGSE-C-IMB-30-A
Porta ingrassatore	PMGSE-C-IMB-31-A
Prolunga ingrassatore	PMGSE-C-IMB-32-A
Anello attacco soffietto	PMGSE-C-IMB-33-A
Tampone	PMGSE-C-IMB-34-A
Micro fine corsa inferiore Tz	PMGSE-C-IMB-35-A
Staffa di bloccaggio asse Tx (Trasporto)	PMGSE-C-IMB-36-A

MGSE (Vertical rotation group)	Drawing
Trave	PMGSE-C-IMC-01-A
Ghiera albero Rz	PMGSE-C-IMC-02-A
Riduttore RV 81U03A/63-V5	PMGSE-C-IMC-03-A
Albero movimentazione riduttore	PMGSE-C-IMC-04-A
Encoder assoluto monogiro	PMGSE-C-IMC-05-A

MGSE (Vertical rotation group)	Drawing
Pignone volantino Rz	PMGSE-C-IMC-06-A
Pignone condotto	PMGSE-C-IMC-07-A
Ruota libera	PMGSE-C-IMC-08-A
Catena trasmissione Rz	PMGSE-C-IMC-09-A
Albero asse Rz	PMGSE-C-IMC-10-A
Albero volantini	PMGSE-C-IMC-11-A
Volantino movimentazione Rz	PMGSE-C-IMC-12-A
Rondella	PMGSE-C-IMC-13-A
Carter catena	PMGSE-C-IMC-14-A
Supporto volantino -2	PMGSE-C-IMC-15-A
Flangia interfaccia attacco Rz	PMGSE-C-IMC-16-A
Supporto cuscinettivolantino-1	PMGSE-C-IMC-17-A
Supporto ruota libera-1	PMGSE-C-IMC-18-A
Perno ruota libera-2	PMGSE-C-IMC-19-A
Supporto cuscinetto albero riduttore Rz	PMGSE-C-IMC-20-A
Flangia encoder asse Rz	PMGSE-C-IMC-21-A
Rondella albero Rz	PMGSE-C-IMC-22-A
Chiavetta albero Rz	PMGSE-C-IMC-23-A
Prigioniero carter catena	PMGSE-C-IMC-24-A
Anello di bloccaggio	PMGSE-C-IMC-25-A
Distanziale pignone volantino Rz	PMGSE-C-IMC-26-A
Distanziale pignone riduttore Rz	PMGSE-C-IMC-27-A
Golfare a occhio circolare M16	PMGSE-C-IMC-28-A
Cannotto protezione encoder Rz	PMGSE-C-IMC-29-A

MGSE (Payload Mock-up)	Drawing
Tubo centrale mock-up	PMGSE-C-IMD-01-A
Disco simulazione peso	PMGSE-C-IMD-03-A
Disco di sicurezza	PMGSE-C-IMD-04-A
Anello di posizionamento	PMGSE-C-IMD-05-A
Colonna mock-up	PMGSE-C-IMD-06-A
Braccio mock-up	PMGSE-C-IMD-07-A
MGSE mock-up (proprietà di massa)	PMGSE-C-IMD-07-A1
MGSE mock-up (complessivo)	PMGSE-C-IMD-07-A2

4. MGSE AXIS DETAILED DESIGN

4.2. MGSE HORIZONTAL MOTION GROUP

This group is used to move the IPL Crate on horizontal axis called TX.
It's composed by a frame where a motorized jackscrew move a base plate mounted over two linear motion guides.
It's designed to move 2300 Kg so ,in order to increase safety ,we verified all components of this group to move a load of 2800 Kg.
The translation speed is 600 mm/min.
Average travel: 1400 mm
Acceleration: 0.15 m/s2
Hour/cycle: 30
This group has drawing number PMGSE-C-IM-02-A1

4.3. MOTOR DRIVE MGSE HORIZONTAL MOTION GROUP.

The jackscrew-ball unit is of type UNIMEC K59 with ratio 1/5 ,recirculating balls screw dia.32x10mm , length rod 2830 mm , it's operated by worm reduction unit of type TECNOINGRANAGGI MP-080-1-10-15'-14-30-60-75 motorized by motor of type CONTROL TECNIQUE 75 UMC301 2.8 Nm-3000RPM (with brake)

jackscrew-ball unit has drawing number : PMGSE-C-IMA-07-A
worm reduction unit has drawing number: PMGSE-C-IMA-09-A
motor has drawing number : PMGSE-C-IMA-10-A

4.4. MGSE VERTICAL MOTION GROUP

This group is used to lift up the IPL Crate on vertical axis called TZ.
It's composed of a frame where a motorized jackscrew move a basement mounted over two linear motion guides.
This group is mounted on the mgse horizontal motion group frame in such a way to have a combination of horizontal and vertical translations.
It's designed to lift 750 Kg so, in order to increase safety, we verified all components of this group to move a load of 950 Kg
The translation speed is 600 mm/min.
Average travel : 1000 mm
Acceleration: 0.15 m/s2
Hour/cycle: 30
This group as drawing number PMGSE-C-IM-01-A1

4.5. MOTOR DRIVE MGSE VERTICAL MOTION GROUP.

The jackscrew-ball unit is of type UNIMEC K59 with ratio 1/5 ,sphere dia.40x10 , length rod 2050 mm, it's operated by worm reduction unit of type TECNOINGRANAGGI MP-080-1-10-15'-14-30-60-75 motorized by motor of type CONTROL TECNIQUE 75 UMC301cacaa by 2.8 Nm-3000RpM (with brake)

jackscrew-ball unit has drawing number : PMGSE-C-IMB-07-A
worm reduction unit has drawing number: PMGSE-C-IMB-10-A
motor has drawing number : PMGSE-C-IMB-11-A

4.6. MGSE VERTICAL ROTATION GROUP

This group is used to rotate the IPL Crate around axis called RZ.
This group is composed by a beam that holds RZ support with the IPL crate group.
The rotation set up is performed in this way: a worm gear reducer is moved through a chain with an hand wheel.
This group is mounted on the mgse vertical motion group frame in such a way as to have a combination of horizontal-vertical translations ; and a rotation control around axis RZ
The rotation max value is 180 degrees
This group has drawing number PMGSE-C-IM-04-A1

4.7. PHYSICAL EFFORT OVER MGSE VERTICAL ROTATION GROUP

The worm reduction unit is of type **M. ROSSI RV81U03A/63V5** with controlled backslash and doubled oil protections. It has the function to rotate **IPL Crate group** around RZ axis. It is operated through a chain with an hand wheel type **ELESA VR 250 FP+IR**

The ratio of worm reduction unit is 1/63 with efficiency 0,5.

The mass of the IPL Crate group and RZ support is 500 Kg (4905 N)

RESULT

Mtout = Fxb = 500x9.81x35x0.1 = 17167.5 Nmm = 17.2Nm (load torque)

Mtin=(17.2/0.5)x(1/63) = 0.5 Nm (input torque)

Fop=0.5/0.125 = 4 N (operator force on hand wheel)

The worm reduction unit type **RV81U03A/63V5** can work at **output nominal torque** of **530Nm** and at output peak torque of **750Nm**.

LEGEND

Mtout: output torque of worm reduction unit

Mtin: input torque of worm reduction unit

Fop: operator force applied to hand wheel rotate the IPL Crate group+RZ support

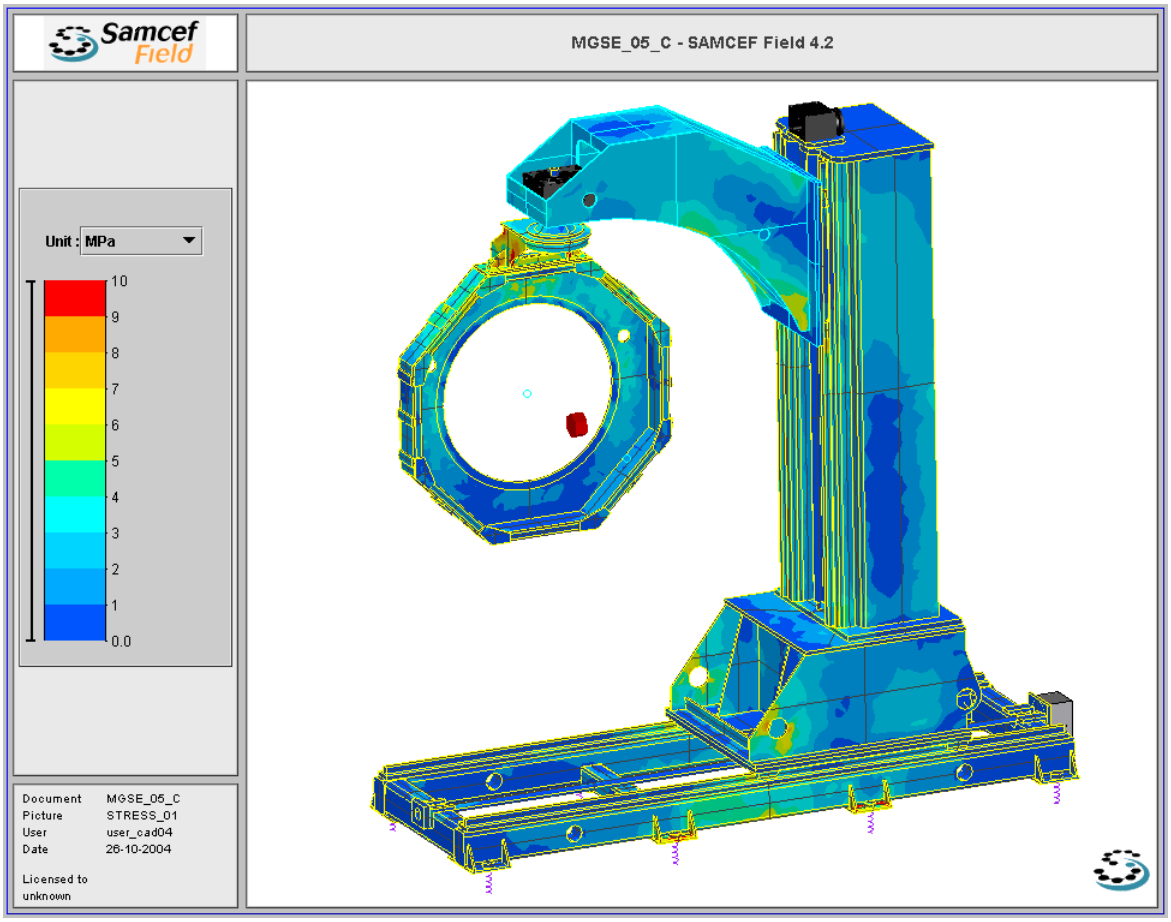
So the worm reduction unit works in safety.

5. FINITE ELEMENTS ANALYSIS

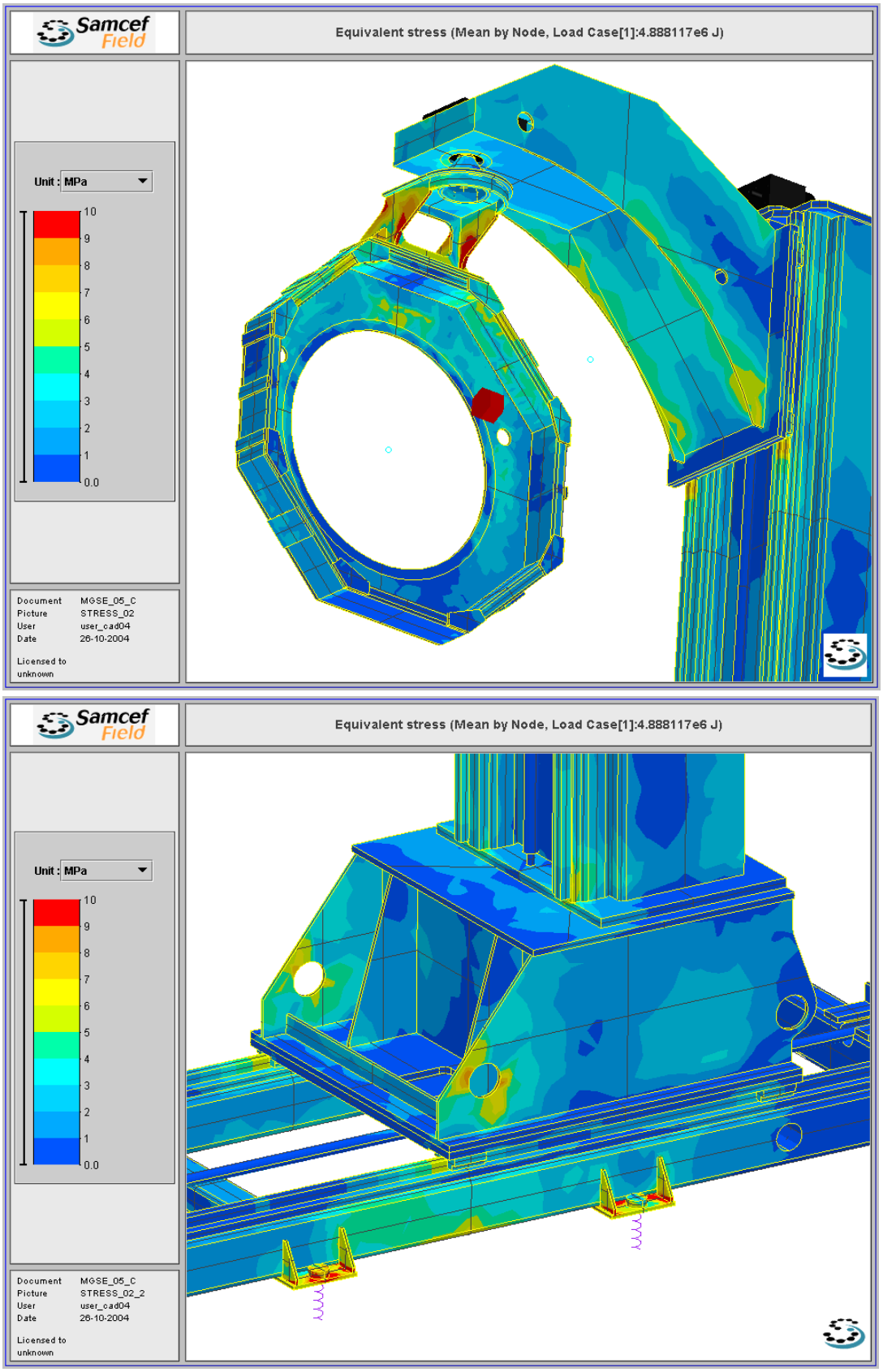
5.2. PAYLOAD CONDITIONS

For calculation we have considered material type :
Steel EN 10025-S275JR (1.0044)
Yield strength :275 MPa , Ultimate strength : 430 MPa
Loads : 330 Kg mass applied at CG of payload that has the following coordinates (X=15 , Y=490 , Z=6 from centre of crate)
The gravity acceleration acts in –Z direction.
The followings pictures show Von Mises stress in Mpa and diplacement in mm.

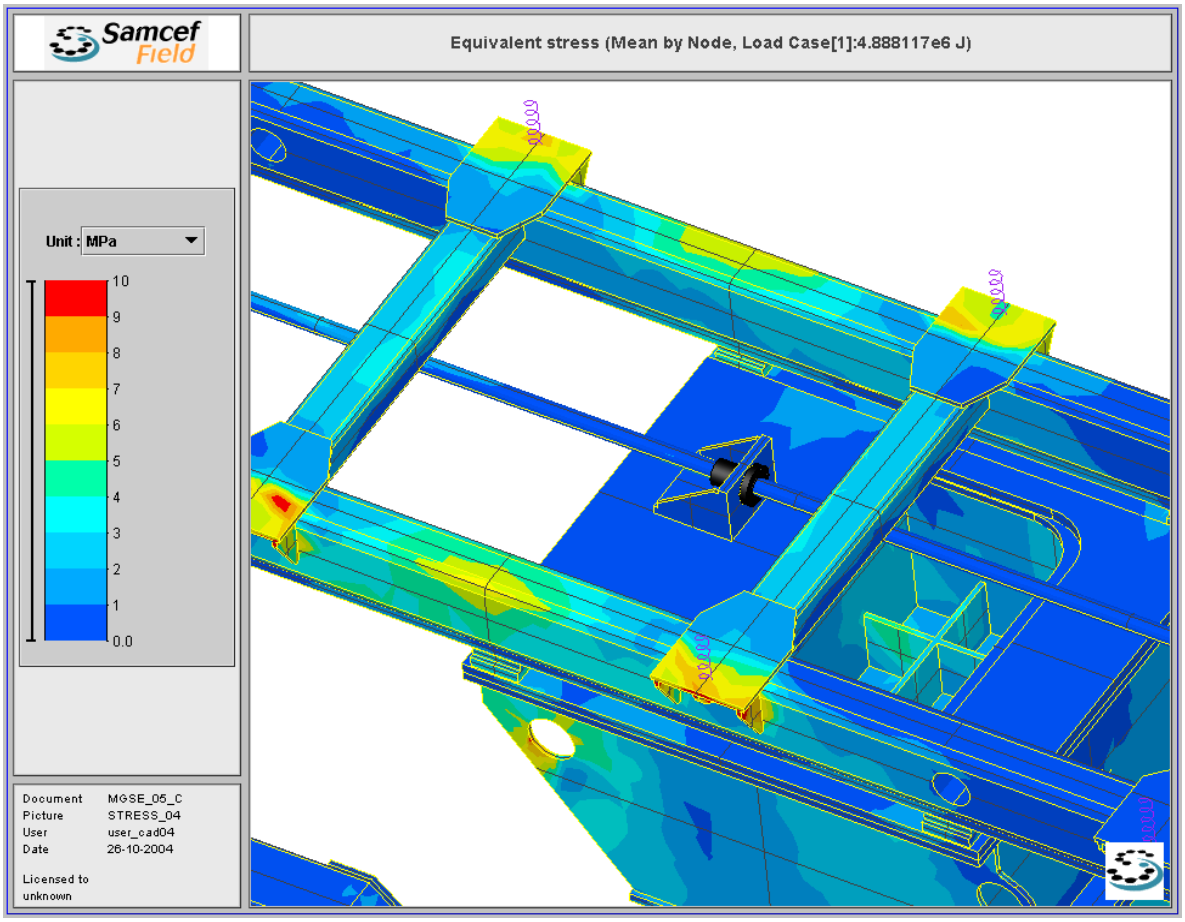
5.3. STRESS ANALISYS



Von Mises stress



Von Mises stress



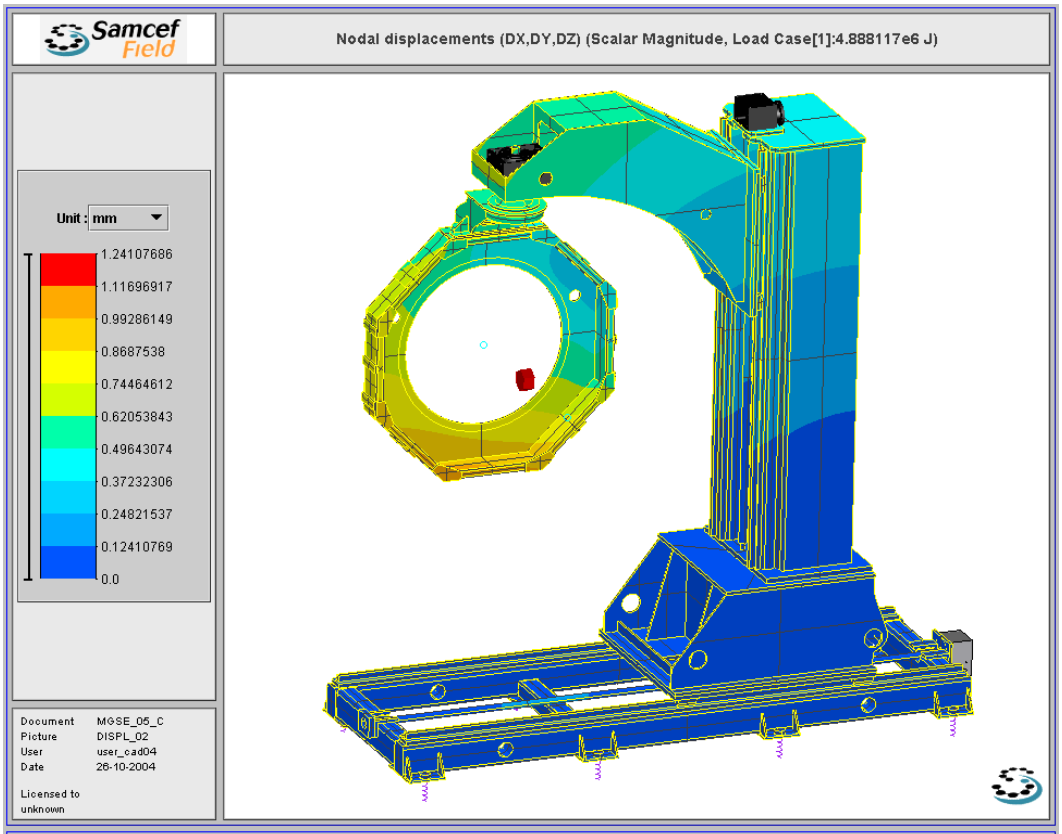
Von Mises stress

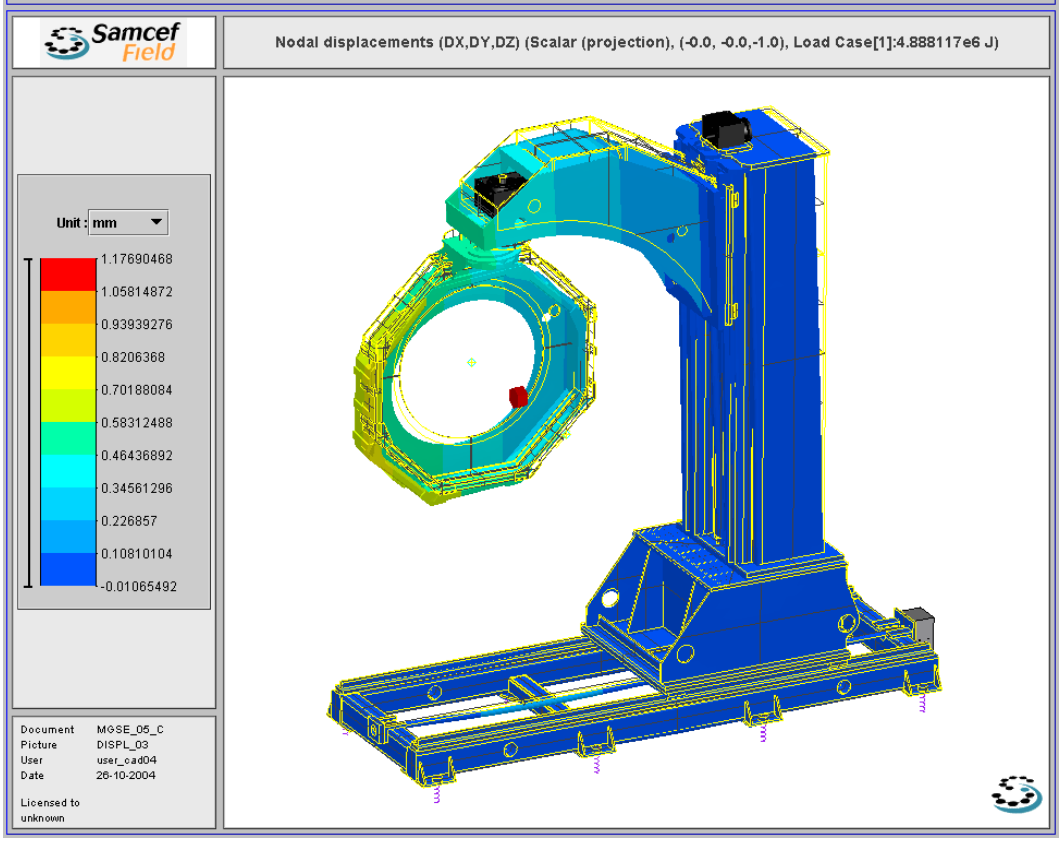
SUMMARY

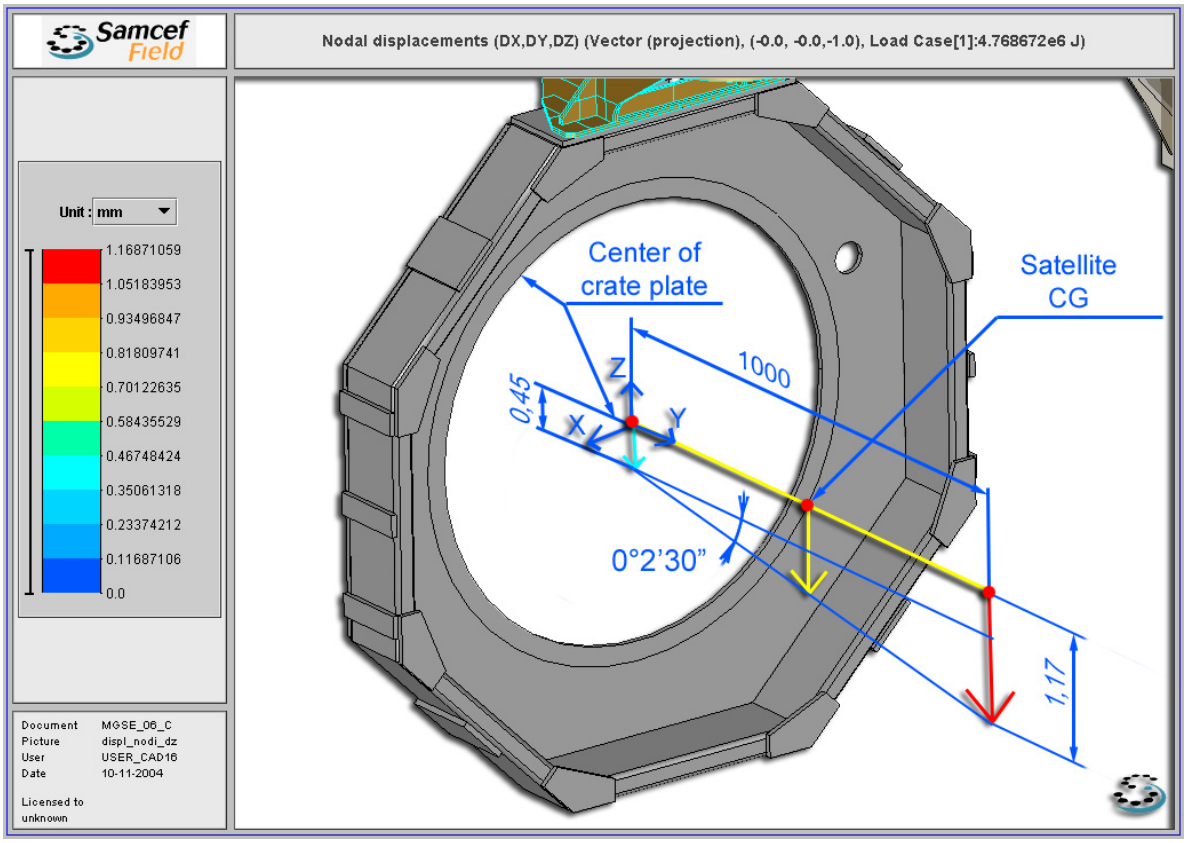
The maximum Von Mises stress of MGSE calibration is 10 Mpa.

The factor of safety against yield is 27.5. and against ultimate is 43
The MGSE calibration works in safety.

5.4. STATIC DISPLACEMENT ANALISYS



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Unit : mm
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Date 10-11-2004
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Satellite CG
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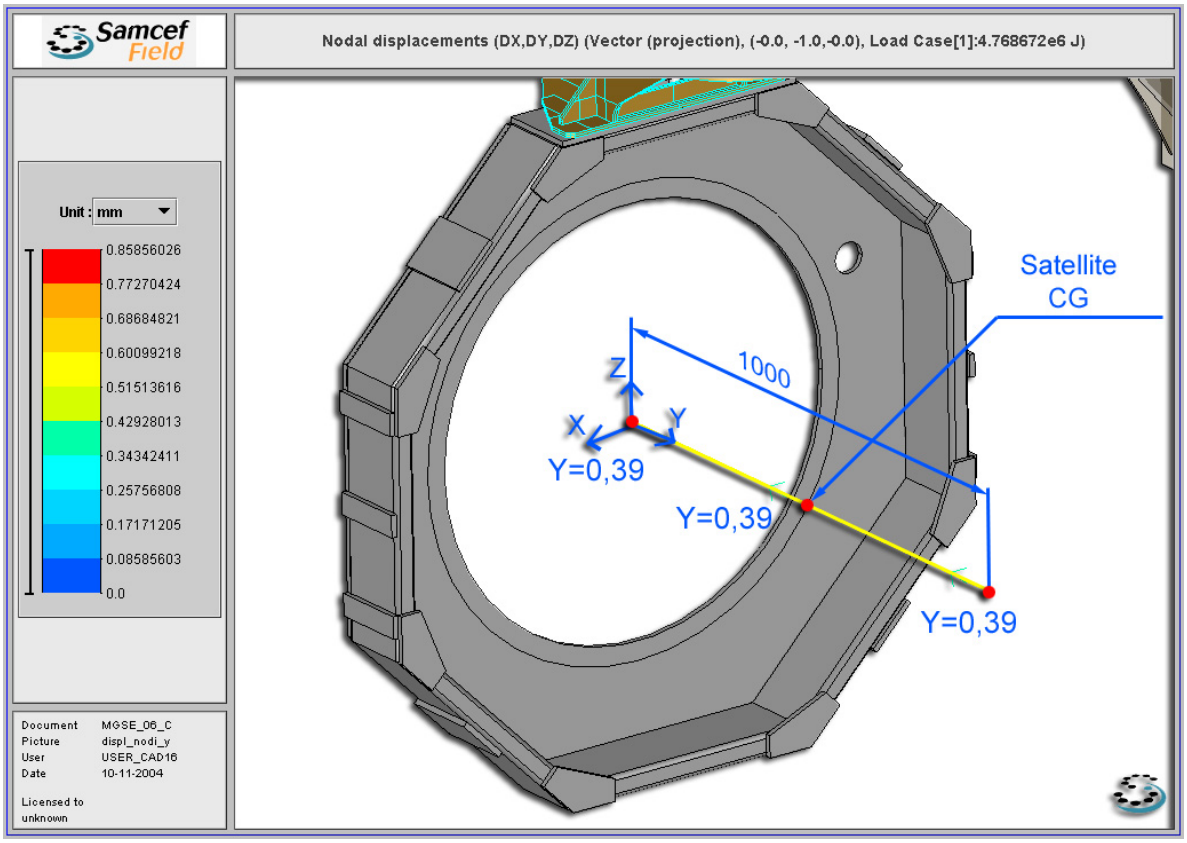
0,45
Z
X
Y
0°2'30"
1,17


Samcef Field
Nodal displacements (DX,DY,DZ) (Vector (projection), (-0.0, -1.0,-0.0), Load Case[1]:4.768672e6 J)
Unit : mm
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0.77270424
0.68684821
0.60099218
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0.34342411
0.25756808
0.17171205
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User USER_CAD16
Date 10-11-2004
Licensed to unknown
Satellite CG
1000
Z
X
Y
Y=0,39
Y=0,39
Y=0,39

SUMMARY

Displacement at centre crate on bearing along –Z axis = 0.45 mm

Axis crate inclination 0°2’30’’

Generic displacement along –Z between 0 and 1000 mm = 0.45+y*0.00072

Displacement at centre crate on bearing along –Y axis = 0.39 mm

Displacement along –Y between 0 and 1000 = 0.39 mm

The displacement values are acceptable.

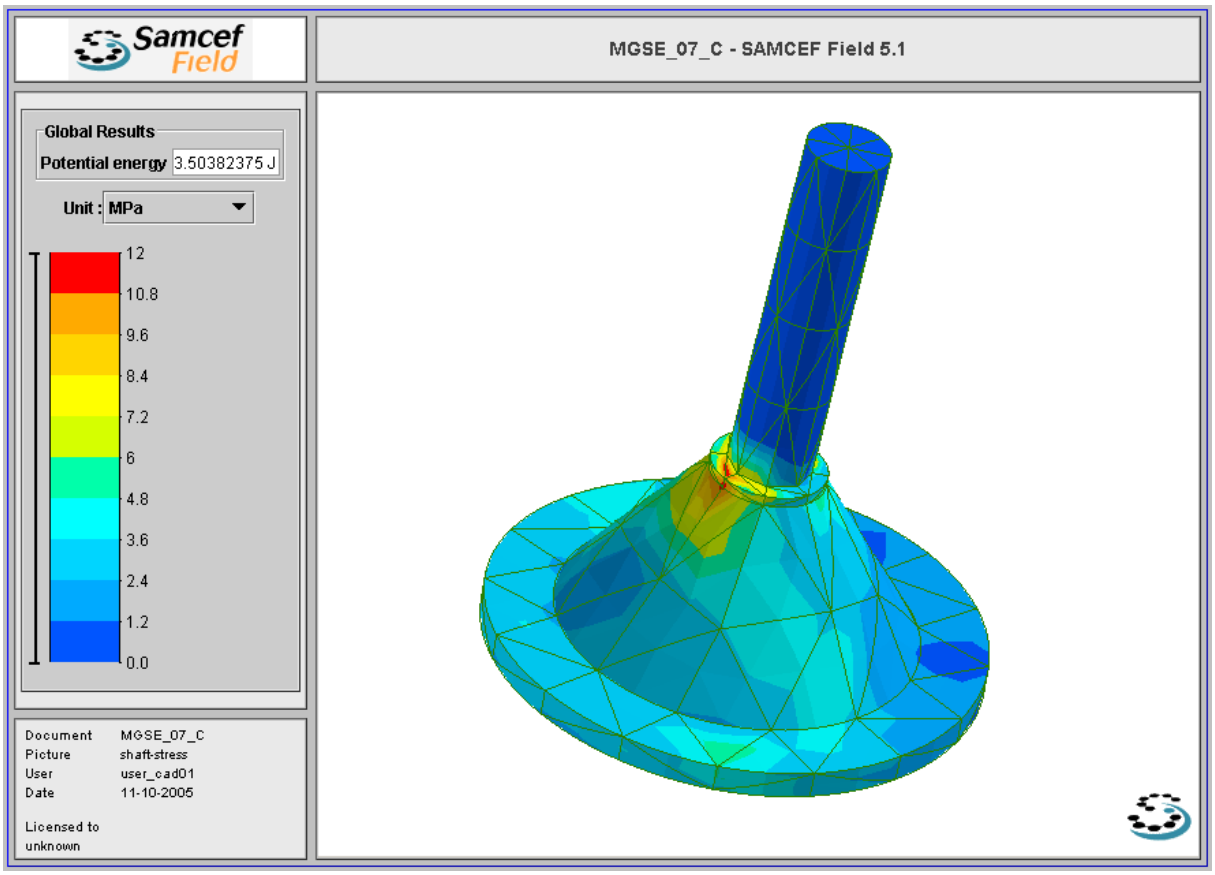
5.5. FLANGE SHAFT FEM CALCULATION

For calculation we have considered material type :

Steel C40 (1.1186)

Yield strength :350 MPa , Ultimate strength : 600 MPa

Loads : Payloads see 5.2



Max Von Mises stress is 12 MPa

Yielding safety is 29

Ultimate safety is 50

6. Lifting features

6.2. Vertical motion group eyebolts

The vertical motion group structure (Figure 6-1) is equipped with N°4 eyebolts type **UNI-ISO 3266-M16** for the handling of the vertical structure alone**.** They have a load capacity of 500Kg (4905N) each.

Figure 6-1 Vertical motion group

6.3. Vertical rotation group eyebolt

The vertical rotation group structure (Figure 6-2) is equipped with N°1 eyebolt type **UNI-ISO 3266-M16** for the handling of the rotation structure alone.

It has a load capacity of 1500Kg (14715N)

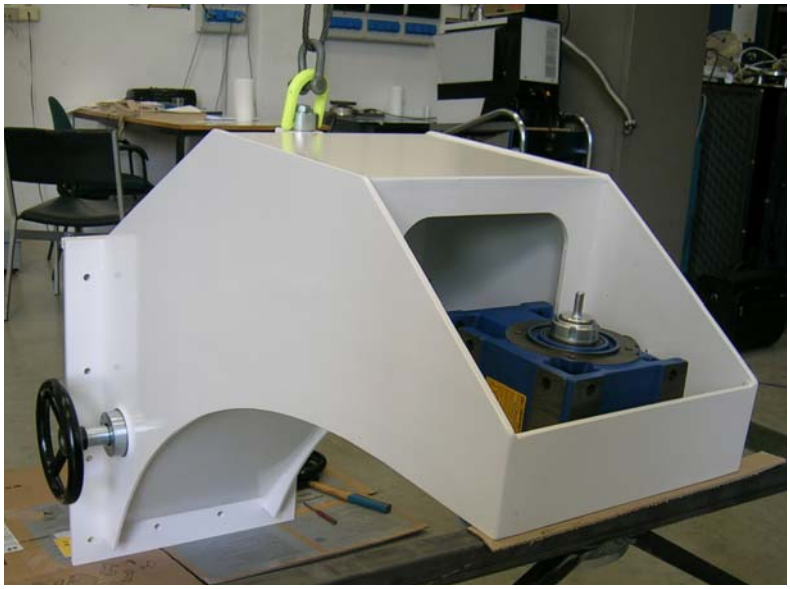


Figure 6-2 Vertical rotation Group

6.4. Calibration MGSE lifting features

The basement of the vertical group structure includes N.4 holes which are suitable for lifting operations of the whole MGSE calibration assembly.

The basement must be fixed to the horizontal structure by means of the yellow flange shown in Figure 6-3 (one for each side).

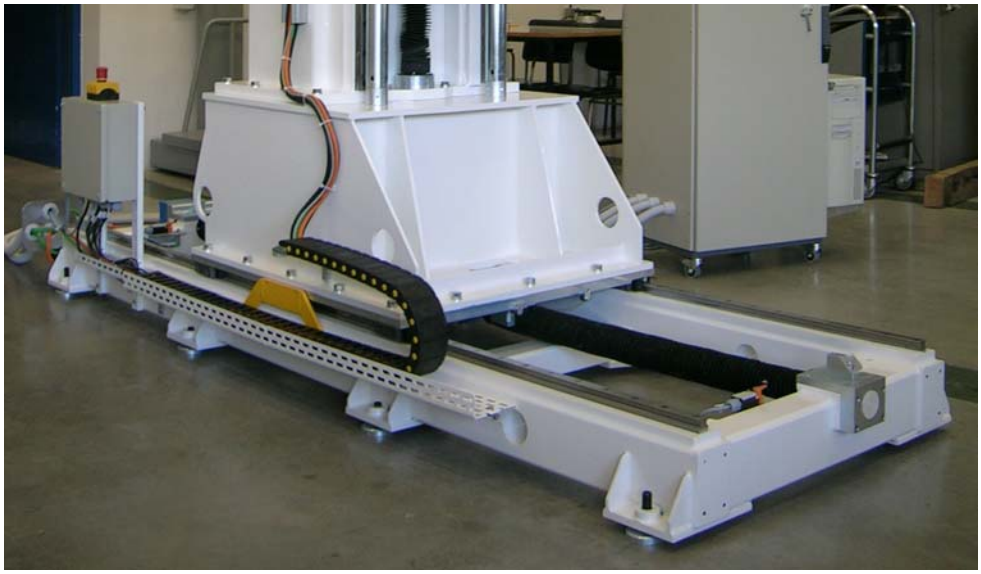


Figure 6-3 MGSE lifting features.

7. LEVELLING SCREWS

The horizontal structure (Figure 7-1) is equipped with N°8 level screws **M20.**. They are suitable for the weight of whole Calibration MGSE assembly (2200Kg - 21582N).

Figure 7-1 Levelling screws

8. TEST REPORT

The **Calibration MGSE** have been tested at INAF Bologna (Italy) in order to verify its functionality, the smoothness of movements, the operator forces applied to move its parts and the load capacity. The Payload mass have been simulated with an additional mass (Payload Mock-up) bolted on Crate with same characteristic of the Payload mass and centre of gravity.

The Payload Mock-up drawings are listed in section 3.

8.2. C.N. AXIS TEST X,Z

Both axis had been checked on a velocity and position repeatability basis.

The values measured are in line with the values specified in the project.

8.3. ORTHOGONALLY TEST BETWEEN AXIS X AND Z

The orthogonally between the guides of Z axes and the X axes had been checked.

The value measured is 0.1mm/1000mm and is in line with the design values.

8.4. SMOOTHNESS TEST RZ AXIS

The chain and worm gear reducer of RZ axis transmission had been checked and it reveals smooth and light.

8.5. STRUCTURE LEVELLING TEST PROCEDURE

The whole structure had been levelled acting on the four levelling screws (named L1,L2,L3,L4 in the following figure).

The correct procedure for best levelling the structure is to level first acting on the external screws (L1 and L4) and then on the internal ones (L2 and L3).

The values obtained are of 0.02mm/1000mm on the X axis measured at both travel ends.

The values obtained are very good and so acceptable.

8.6. STRUCTURE TEST UNDER PAYLOAD

In order to check the deflection under Payload force (here simulated with a Mock up of 235kg), we read the deflections Rz support flange (C1 point in Figure 8-1) compared to the calculated displacement.
The maximum deflection appears at point C1 and is about 0.5mm (0.45 mm predicted from FEM analysis).
The value is very small and corresponds to a deflection of 1.2 mm at 1 meter of distance from the Payload attach.

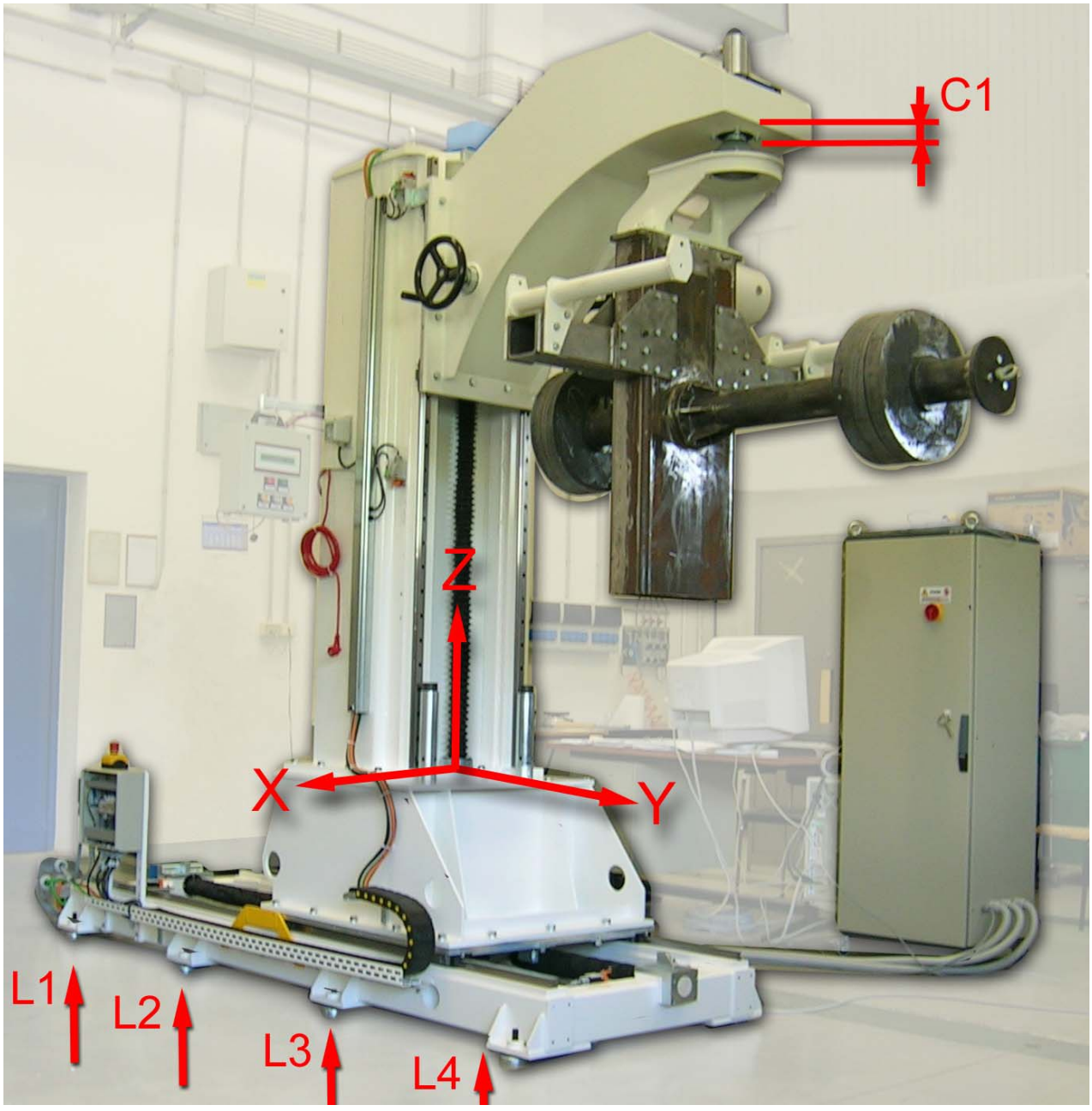


Figure 8-1 Structure test configuration

9. GROUP CONFORMANCE

AFTER THE FINAL CALCULATIONS AND TESTS THE MGSE CALIBRATION GROUP RESULTS WELL ALIGNED WITH INITIAL DESIGN SPECIFICATIONS AS WRITTEN IN DOCUMENT: AGILE-ITE-SR-006 “AGILE Integrated Payload IASF MGSE Requirement Specifications”, Issue 1, November 2003.