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Change Record

Issue	Date	ECN Number	Section(s) Affected	Description of Change/Change Request Reference/Remarks
A	7/31/03	03-0584	All	Original Release
B	9/15/03	03-0776	4.4.1, 4.4.2, 4.4.3, 4.5, 4.6	Update to include changed from PDR
C	6/8/04	04-0584	3, 4.4.2, 4.4.3, 5, 6	Update for FDR actions

Table of Contents

1 Introduction

The Lateral Support is a pneumatic linear actuator intended for y-axis support of the VISTA M1 mirror. Twelve Lateral Supports are positioned above the mirrors x-axis and operate in tension and twelve Lateral Supports are positioned below the x-axis and operate in compression. Two designs exist to address the different load applications. The design differences between the compression and tension versions are minor and the primary components are common to both. Both versions utilize a rolling element diaphragm in a piston/cylinder arrangement to generate a force output from a controlled pressure input. Where applicable, the differences will be addressed as related to design considerations and specification requirements.
The purpose of this report is to document the design of the Lateral Support and verify conformity to the design requirements set forth by VISTA.

2 Acronyms and Abbreviations

VER	VertexRSI
VIS	VISTA
TRE	Technical Report
XXXX	The next sequential number in the series of documents

3 Applicable and Referenced Documents

AD	Title	Number & Issue
AD01	Technical Specification for the Telescope Structure Work Package	VIS-SPE-ATC-01000-0006
AD02	Interface Control Document between M1 Mirror and M1 Cell	VIS-ICD-ATC-02000-03000
AD03	Primary Mirror Interface to Mirror Cell	VIS-DWG-ATC-02000-03000
AD04	VLT Environmental Specification	VLT-SPE-ESO-10000-0004
AD05	Lateral Compression Actuator Assembly	VIS-DWG-VER-03001-4520
AD06	Lateral Tension Actuator Assembly	VIS-DWG-VER-03001-4521
AD07	Verification Plan For: Lateral Support	VIS-TRE-VER-03001-0106
AD08	Test Report For: Lateral Support	VIS-TRE-VER-03001-0712

Refer to the latest issue of all applicable documents.

4 Design Report

4.1 Scope of the Design

This report describes in component level detail the design of the Lateral Support as related to the various VISTA requirements. The design, material selection and performance of each component as well as the assembly are correlated to the specific requirements, and where applicable, calculations are included. The Lateral Support is defined as the pneumatic assembly only. The control system is not included in the scope of this report.

4.2 Assumptions

- Friction effects internal to the pneumatic cylinder are negligible (addressed at test)
- Air supply is filtered and dry at 7.9 bar minimum
- One design for all 12 compression versions
- One design for all 12 tension versions

4.3 Materials

The following materials are used in the construction of the Lateral Supports. Refer to drawings AD05 and AD06 for detailed component drawings.

4.3.1 Stainless Steel per ISO 683/13 4

Used for:
S780-4521-14 Rod
S780-4521-16 Rod

High strength alloy selected for tension rods.

Physical Properties:
Density: 7.8 g/cm^3

Mechanical Properties:
Tensile Strength: 345 MPa
Ultimate Strength: 655 MPa
Modulus of Elasticity: 200 GPa

4.3.2 Stainless Steel per ISO 683/13 11

Used for:
S780-4521-15 Cross Member

Physical Properties:
Density: 8.0 g/cm^3

Mechanical Properties:
Tensile Strength: 215 MPa
Ultimate Strength: 505 MPa
Modulus of Elasticity: 200 Gpa

4.3.3 Stainless Steel per ISO 683/13 7

Used for:
S780-4520-11 Flange

Physical Properties:
Density: 7.8 g/cm^3

Mechanical Properties:
Tensile Strength: 275 MPa
Ultimate Strength: 515 MPa
Modulus of Elasticity: 200 GPa

4.4 Design Description

4.4.1 Theory of Operation

The Lateral Supports are pneumatic linear actuators that apply a force to the M1 mirror by application of air pressure on a piston face. The pneumatic cylinder used in the design is a Control Air product that features a rolling element diaphragm enclosed in an aluminium cylinder. An enclosed piston drives an output shaft that is supported by a linear bearing. A single acting cylinder (extension with applied pressure) was selected for both the compression and tension supports for friction concerns. A double acting cylinder (capable of retraction with applied pressure) has more internal friction due to an additional seal between the output shaft and the housing.
To apply the same cylinder to both applications, the extension action was placed between the mirror and structure attachment points for compression and outside the attachment points for tension. Refer to the Figures 1 and 2 for the two configurations.

Figure 1: Lateral Compression Support

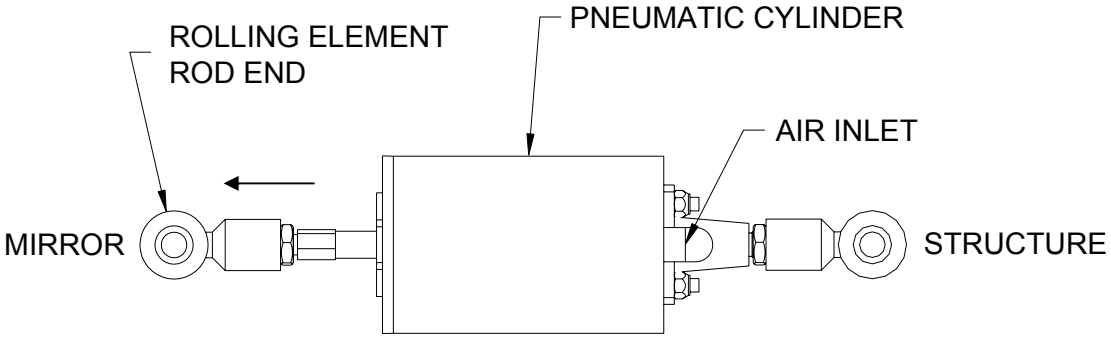
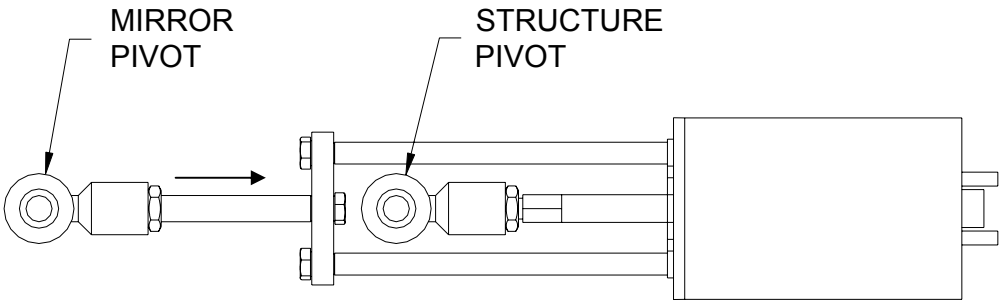


Figure 2: Lateral Tension Support



An obvious difference in the two designs is the mass distribution. To meet the mirror pivot forces indicated in AD03, the mass of the attachment bracket (pivot to mirror pad) will be varied.

The pneumatic cylinders also contain a spring that loads the piston in the retracted direction. The spring is present to increase the response time of the support at low operating pressures. When a decrease in force is commanded, the pressure in the cylinder volume (V_c) is discharge to the atmosphere. At high operating pressures, the pressure differential between V_c and the atmosphere is large and the response is rapid. At low operating pressures, the pressure differential is small and response is slower. The presence of a spring preload provides a positive offset to the entire operating pressure range.

The travel of the cylinder is very long (60 mm), so there is no need for a fine length adjustment. Operation will be about a nominal extension of 10mm with rough adjustment (+/- 2 mm) done by way of the rod ends.

4.4.2 Requirements

Table 1 indicates the VISTA requirements that are addressed in this report.

Table 1: VISTA Requirements

Section	Description	Criteria
AD01 10.4.6 (a)	24 Lateral Supports arrange in accordance with AD03	Design
AD01 10.4.6 (c)	Use of Bellofram rolling element diaphragm	Design
AD01 10.4.6 (d)	12 Compression and 12 Tension	Design
AD01 10.4.6 (f)	Equipped with low friction bearings in pivots	Design
AD01 10.4.6 (g)	Equipped with manual length adjustment	Design
AD01 10.4.6 (h)	Easy disconnect and re-connect	Design
AD01 10.4.6 (i)	Stow safely during M1 removal	Design
AD01 10.4.6 (j)	Range of force output	10 to 2700 N
AD01 10.4.6 (k)	Absolute accuracy of an individual support	≤ 13.7 N
AD02 5.3.2	Z-axis force at mirror pivot	AD03 Table

4.4.3 Verification by Design

4.4.3.1 AD01 Section 10.4.6(a)

Per Section 10.4.6 (a), the Lateral Support system is to be arranged per AD03. The M1 Cell Structure controls the mounting locations of the supports and is being designed per the support positions defined in AD03.

4.4.3.2 AD01 Section 10.4.6(c)

Force actuators used in the conceptual design featured a rolling element Control Air diaphragm. A Control Air cylinder (equipped with a rolling element diaphragm) that is suited for the target force and pressure parameters was selected and implemented into the design. Specifications for the cylinder are as follows:

Part Number: 239-314-232
Diaphragm Material: Neoprene with Dacron fabric
Body: Aluminum
Rod: Chrome plated steel
Working Pressure: 7.1 bar
Maximum Pressure: 10 bar
Effective Pressure Area: 38.7 cm^2
Spring Rate: 0.7 N/mm

Pressure and force parameters based on this diaphragm are discussed in detail in Section 4.4.3.8 and calculations are shown in Section 4.5.

4.4.3.3 AD01 Section 10.4.6(d)

Per Section 10.4.6 (d), the Lateral Support system shall consist of 12 compression supports and 12 tension supports attached at the perimeter of the M1 Mirror. Two designs have been created for tension and compression application. Individual supports of each type are identical for commonality of parts and spares consideration.

4.4.3.4 AD01 Section 10.4.6(f)

Low friction bearings shall be used for both pivot ends. Roller bearing rod ends from Durbal Inc. have been selected. Friction values are not available from Durbal so parts were acquired for evaluation and tested. Specifications are as follows:

Manufacturer: Durbal Inc.
Part Number: BRTF12-04-501
Dynamic Load Rating: 10250 N
Static Load Rating: 6600 N
Pin Size: 12 mm
Thread: M12 x 1.75 (female)

4.4.3.5 AD01 Section 10.4.6(g)

Each support shall be equipped with manual length adjustment for centring of the diaphragm. Adjustment of the support length is accomplished through the rod ends with 2 mm of adjustment available at each end.

4.4.3.6 AD01 Section 10.4.6(h)

AD01 Section 10.4.6(h) requires easy disconnection and re-connect of the lateral supports from the mirror. Removing one shoulder bolt at each pivot allows the unit to be removed.

4.4.3.7 AD01 Section 10.4.6(i)

AD01 Section 10.4.6(i) requires that the supports stow safely during M1 removal. Due to the limited space available around the perimeter of the mirror, stow brackets are not possible. Instead, by disconnecting both pivots and reconnecting the actuator's mirror pivot to the structure bracket, the actuator is safely stowed on the structure.

4.4.3.8 AD01 Section 10.4.6(j)

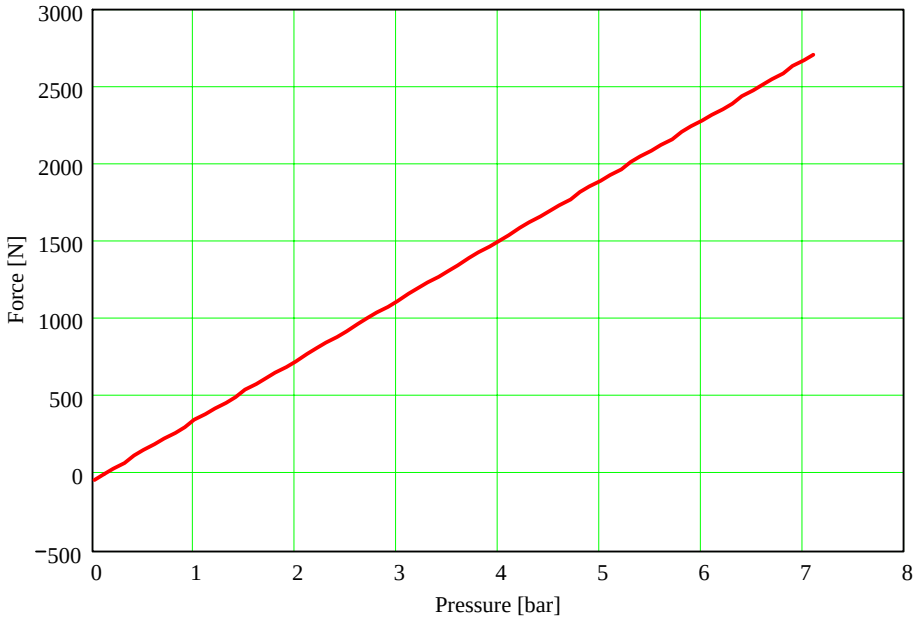
The range of force output shall be 10 to 2700 N. The force output is a linear function of piston area, pressure, and spring force. For input pressures of 0 to 7.10 bar, the force output is –47 to 2700 N (negative indicating opposite of operational direction). Note that in the non-operating condition, 24 lateral supports will apply a combined 1100 N of force in the negative Y direction. The following equation applies for the entire pressure range:

$$F = (P \times A) - K(\Delta x)$$

where F = Force Output
P = Pressure In
A = Effective Piston Area (38.7 cm^2)
K = Spring Rate (0.7 N/mm)
Δx = Spring compression from free length (57.1 mm)

Figure 4 shows the force output as a function of pressure.

Figure 4: Force Output vs Pressure



Conformance with the 10 to 2700 N range requirement demands that the air input be controllable through a minimum range of 0.12 to 7.1 bar. The control valve selected (Bellofram T2000 series) provides a controlled output from 0 to 8.62 bar.

4.4.3.9 AD01 Section 10.4.6 (k)

AD01 Section 10.4.6(k) requires that the accuracy of an individual support shall be less than ± 13.7 N. No manufacturer data is available, so the units were tested for compliance. Refer to AD08 for test results.

4.4.3.10 AD02 Section 5.3.2

The section 5.3.2 requirement states that Z-axis force at mirror pivot when zenith facing shall be 35 N ± 1 N. To achieve the 35 N pivot loads, the masses of the pivot brackets (to the M1 pad) were derived from the mass properties of the supports. The mass properties of the Lateral Supports and associated brackets are:

Table 3: Support Mass Properties

Support	Mass [kg]	CG [mm] to Structure Pivot	Pivot to Pivot [mm]	Resulting mirror Pivot Load	Addition For 35 N	Required Mass
Compression	1.41	171.6	336	7.06 N	27.94 N	2.85 kg
Tension	1.70	-82.5	170	-8.09 N*	43.09 N	4.39 kg

*Negative pivot load sign indicates that the resultant force is opposite the desired direction

For each support, the hardware used contributes 1.056 N to the required 35 N. The remaining force is created by brackets with the following mass properties:

Lateral Compression Bracket: 2.74kg
Lateral Tension Bracket: 4.28

5 Calculations

Pneumatic Cylinder Specifications

Manufacturer: Control Air
www.controlair.com
Description: Size 6 Super Cylinder
Part Number: 239-314-232

Unit Definitions

$kPa := 10^3 \cdot Pa$ $bar := 1 \cdot 10^5 \cdot Pa$

$A_e := 38.71 \cdot cm^2$ Effective Piston Area

$S := 60 \cdot mm$ Maximum Stroke

$F_{preload} := 40 \cdot N$ Return Spring Preloac

$K := 7 \cdot \frac{N}{cm}$ Spring Rate

Operating Parameters

$F_{min} := 10 \cdot N$ Minumum force output per Tech Spec Sect 10.4.6j

$F_{max} := 2700 \cdot N$ Maximum force output per Tech Spec Sect 10.4.6j

$F_{acc} := 10 \cdot N$ Absolute Accuracy +/-

$F_r := 1.5 \cdot N$ Output Resolution +/-

Force Output

$$P_{preload} := \frac{K \cdot \left(10 \cdot mm + \frac{F_{preload}}{K} \right)}{A_e}$$ Pressure to overcome spring preload at 10 mm position

$P_{preload} = 0.121 bar$

$$F(P, x) := P \cdot A_e - K \cdot \left(x + \frac{F_{preload}}{K} \right)$$ Force output as a function of pressure and piston position

Assume the actuator is operating about 10 mm of cylinder extension (x = 10 mm)

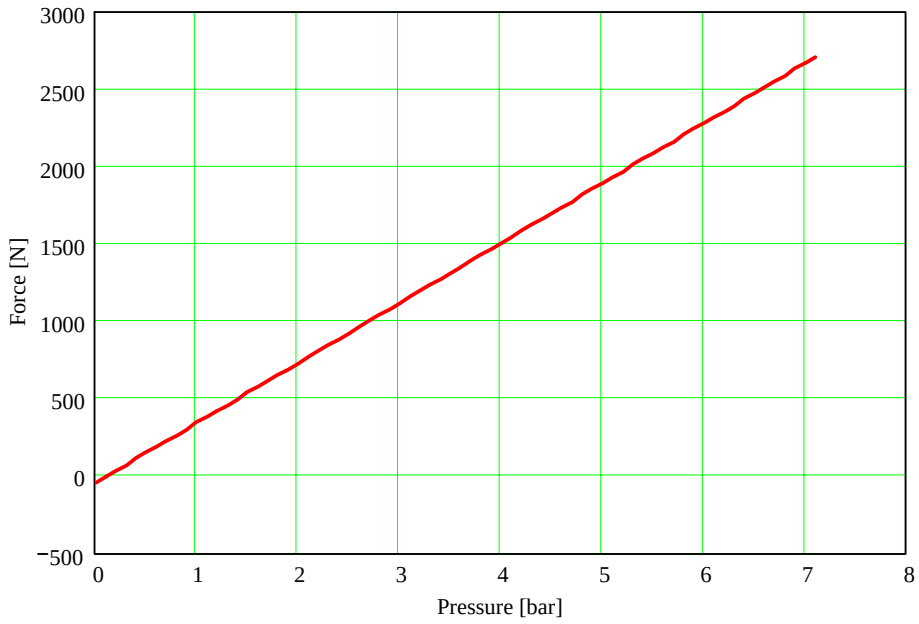
$F(0\cdot bar, 10\cdot mm) = -47\,N$ Static Load with no air pressure

$F(7.1\cdot bar, 10\cdot mm) = 2701\,N$ Maximum commanded pressure = 7.1 bar

$F(.121\cdot bar, 10\cdot mm) = -0.16\,N$ Minimum commanded pressure = .18 bar

$P := 0\cdot bar, .1\cdot bar .. 7.1\cdot bar$ Set pressure range variable

Force Output vs Pressure



Affect of spring rate on force output for +/-1 mm travel

$F(7.1\cdot bar, 9\cdot mm) = 2702.110N$

$F(7.1\cdot bar, 10\cdot mm) = 2701.410N$

$F(7.1\cdot bar, 11\cdot mm) = 2700.710N$

6 Conclusions

The design for the Lateral Support conforms to the requirements indicated in Table 1. For test procedures and verification methods for requirements not included in the scope of this report, refer to Verification Plan For: Lateral Support (VIS-TRE-VER-03001-0106)

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