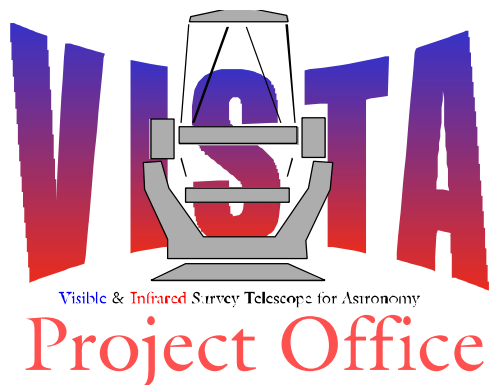




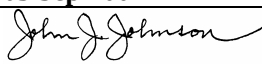
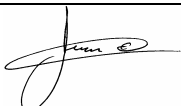
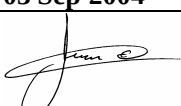
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Change Record

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
1.0	08/08/03	All	First Issue
2.0	10/09/03	4.2, 4.3 Table, 4.5.5	Per TELS_PDR_104 RID, parameter table has been updated and added assumptions note. Added Cass imbalance allocated, updated Cass calculations
2.0	10/09/03	4.5.2 Table, 4.5.4 Table	Per TELS_PDR_106 RID, the maximum motor torque has been amended.
2.0	10/09/03	4.2, 4.5	Per TELS_PDR_123 RID, the dynamic brake capacity has been updated.
2.0	10/09/03	4.6	Per TELS_PDR_71 RID, the bleeder valve recommendation has been deleted.
2.0	10/09/03	4.3, 4.5.4, 4.6	Amended ALT brake capacity by adding 2 additional brakes.
2.0	10/09/03	3, 4.3	Added more reference documents and source column to Section 4.3 table
2.0	10/09/03	4.3, 4.5	Per RID No. TELS_PDR_60, inconsistencies between have been corrected.
3.0	03/09/04	4.3	Added CASS Cablewrap motor and brake sizing parameters
3.0	03/09/04	4.5.7, 4.5.8 (New)	Added CASS Cablewrap Motor & Brake Sizing Results
3.0	03/15/04	4.3, 4.5	Updated AZ/ALT Inertia Values
4.0	05/27/04	Signature Block	Per TELS_FDR1_038, added 2 nd person's approval to signature block
4.0	05/27/04	4.2, 4.3, 4.4.2, 4.5.2, 4.5.4, 4.5.6 & 4.5.8	Per TELS_FDR1_70, used manufacturer's brake reaction time
4.0	5/27/04	3	Added AD08 reference
4.0	5/27/04	4.3, 4.5	Updated parameter values/results per revised Ads
5.0	8/5/04	4.3, 4.5.4, 4.6	Updated parameter values/results for higher capacity ALT brakes (TELS_FDR1_071 & TELS_FDR2_211).
6.0	9/3/04	Table 4.3.2, 4.5.5 – 4.5.8, 4.6	Updated parameter values/results for correct CASS/CASS CW motor

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1 Introduction

Motor and Brake sizing analysis will be shown to justify that the selection of drive components are fully compliant to the requirements of AD01 Technical Specification.

2 Acronyms and Abbreviations

ALT	Altitude Axis
AZ	Azimuth Axis
CASS	Cassegrain Rotator Axis
VER	VertexRSI
VIS	VISTA
TRE	Technical Report

3 Applicable and Referenced Documents

In this section all the documents referred to in the Analysis Report shall be listed.

Title		Number & Issue
AD01	Technical Specification for the Telescope Structure Work-Package	VIS-SPE-ATC-01000-0006 Issue 3.0
AD02	Control System Design Report	VIS-ANA-VER-01001-9002 Issue 5.0
AD03	Weight and Centre of Gravity Analysis	VIS-ANA-VER-01001-0250 Issue E
AD04	Drive Analysis (AZ axis)	VIS-ANA-VER-01001-0254 Appendix A Issue D
AD05	Design Report For: Component Selection	VIS-TRE-VER-01001-0706 Issue C
AD06	Technical Proposal, Reference Tender 1447	VISTA PROPOSAL, dated July 25, 2002
AD07	Cablewrap Design Report, CASS Wrap	VIS-TRE-VER-04001-0750 Appendix B Issue B
AD08	Drive Analysis (CASS axis)	VIS-ANA-VER-01001-0254 Appendix B Issue D

4 Analysis Report

4.1 Scope of the Analysis

This analysis report consists of the Azimuth, Altitude, Cassegrain Rotator and Cassegrain Rotator cablewrap motor and brake analysis. It will be shown that the components chosen for this design, will yield compliance to the following specifications of AD01:

AD01 Spec	VISTA SPECIFICATION
8.3	AZ Velocity $\pm 2^{\circ}/\text{sec}$ ALT Velocity $\pm 2^{\circ}/\text{sec}$ CASS Velocity $\pm 3.6^{\circ}/\text{sec}$ AZ Acceleration $\pm 0.5^{\circ}/\text{sec}^2$ ALT Acceleration $\pm 0.5^{\circ}/\text{sec}^2$ CASS Acceleration $\pm 1.0^{\circ}/\text{sec}^2$
11.1.4.1 11.1.10	100% Overhead Margin Cassegrain Braking Deceleration Azimuth $4^{\circ}/\text{sec}^2$ to $60^{\circ}/\text{sec}^2$ Altitude $8^{\circ}/\text{sec}^2$ to $60^{\circ}/\text{sec}^2$ Cassegrain $16^{\circ}/\text{sec}^2$ to $120^{\circ}/\text{sec}^2$ Brakes shall have the capacity to resist the maximum motor torque combined with survival wind loading (36 m/s max)

4.2 Assumptions

All of the motor sizing analysis shown will be with all motors active in their respective axes (4 motors active in AZ, 2 motors active in ALT, 2 motors active in CASS (+ cablewrap motor) since there is no requirement for less than full motor operation.

Motor amplifier should be de-rated per the manufacturer's specifications given below:

De-rate 5 % / 300 meters above 1,000 meters above sea level

Vista Altitude 2630 m

De-rate amplifiers by: $2630 \text{ m} - 1,000 \text{ m} = 1630 \text{ m}$
 $1630 \text{ m} / 300 \text{ m} = 5.43$
 $5.43 \times 5\% = 27.2\%$

The motors are not de-rated since they are actively cooled. Additionally for the Altitude motors, the considerable heat sink aids in keeping the motor close to ambient temperature.

The inertia of the gearbox is defined at the low speed end. The efficiency does not effect the translation to the high-speed side. This is based on the assumption that the first gear pass encounters the majority of the inertia.

The inertia and friction of the tachometer is negligible, thus omitted in the calculations.

4.3 Motor and Brake Sizing Parameters

Following are the motor and brake parameters used. The information was obtained from the AD03, AD04, AD05 and AD06 sources listed in Section 3. The Source column shows the origin for the given parameter value.

Table 4.3.1 AZ/ALT Parameters

PARAMETER	SYMBOL	AZ	ALT	SOURCE
MOUNT AXIS LEVEL PARAMETERS				
Inertia, kg-m ²	J _{STR}	534,191	195,335	AD03
Coulomb Friction, N-m	F _{STR}	2,439	542	AD04
Unbalance, N-m	UB	0	200	AD04
MOTOR LEVEL PARAMETERS				
Motor Friction, N-m	F _{MTR}	0.385	40.67	AD05
Motor Inertia, kg-m ²	J _{MTR}	0.00657	6.83	AD05
Brake Inertia, kg-m ²	J _{BRK}	3.24e-4	3.244	AD05
Gear-Box Inertia (combined) LSS, kg-m ²	IJ _{GB}	171.2	N/A	AD04
Gear-Box Coulomb Friction (Combined) HSS, N-m	F _{GB}	0.008	N/A	AD04
Gear-Box Viscous Friction, HSS, N-m/°/s	FV _{GB}	0	N/A	AD04
GENERAL MOUNT PARAMETERS				
Motor to Axis Gear Ratio	N	14,750	1.0	AD04
Gear-Box Ratio (combined)	N _{GB}	745.64	N/A	AD04
Gear-Box Forward Drive Efficiency (Combined)	E	78.3%	100%	AD04
Axis Acceleration, °/s ²	A	1.0	1.0	AD06
Wind Torque Constant, N-m/(m/s) ²	KWT	14.86	16.02	AD04
Number of Motor per Axis	NM	4	2	AD06
MOTOR/BRAKE PARAMETERS				
Motor Capacity, KW	KW	7.2	0.0958	AD05
Motor Speed, RPM	RPM	5000	0.333	AD05
Motor Torque Constant, N-m/amp	KT	0.63	160	AD05
Motor Rated Current, amp	RMC	27.2	20	AD05
Motor Rated Torque, N-m	RT	17	2,742	AD05
Motor Peak Torque, N-m	PRT	48.30	4,067	AD05
Preload Level (RT %)	PLD	25%	0%	DESIGN
Brake Reaction Time, sec	BRK _T	0.05	0.15	AD05
Brake Rating (Static), N-m	BRK _{STA}	22	17,980	AD05
Brake Rating (Dynamic), N-m	BRK _{DYN}	22	17,980	AD05
Motor Controller Rated Current, A	AMP _{RTD}	30	30	AD05
Motor Controller De-Rated Current, A	AMP _{DRTD}	21.9	21.9	CALC

For Altitude, the Brake Rating Capacity, BRK_{STA} and BRK_{DYN} is for a brake pair (2 brakes) since two brakes will be provided per motor to meet the Technical Specification.

Table 4.3.2 Cass/Cass Cablewrap Parameters

PARAMETER	SYMBOL	CASS	CASS CW	SOURCE
MOUNT AXIS LEVEL PARAMETERS				
Inertia, kg-m^2	J_{STR}	888	1,233	AD08,07
Coulomb Friction, N-m	F_{STR}	250	250	AD08,07
Unbalance, N-m	UB	781	1,049	AD08,07
MOTOR LEVEL PARAMETERS				
Motor Friction, N-m	F_{MTR}	0.132	0.132	AD05
Motor Inertia, kg-m^2	J_{MTR}	0.00114	0.00114	AD05
Brake Inertia, kg-m^2	J_{BRK}	62e-6	62e-6	AD05
Gear-Box Inertia (combined) LSS, kg-m^2	I_{GB}	9.11	67e-6	AD08,07
Gear-Box Coulomb Friction (Combined) HSS, N-m	F_{GB}	0.160	0.142	AD08,07
Gear-Box Viscous Friction, HSS, $\text{N-m}^\circ/\text{s}$	FV_{GB}	0	0	AD08,07
GENERAL MOUNT PARAMETERS				
Motor to Axis Gear Ratio	N	5,850	3,757	AD08,07
Gear-Box Ratio (combined)	N_{GB}	450	100	AD08,07
Gear-Box Forward Drive Efficiency (Combined)	E	86.6%	92.1%	AD08,07
Axis Acceleration, $^\circ/\text{s}^2$	A	2.5	2.5	AD06
Wind Torque Constant, $\text{N-m}/(\text{m/s})^2$	KWT	0.038	0.038	AD08,07
Number of Motor per Axis	NM	2	1	AD06
MOTOR/BRAKE PARAMETERS				
Motor Capacity, KW	KW	1.6	1.6	AD05
Motor Speed, RPM	RPM	3600	3600	AD05
Motor Torque Constant, N-m/amp	KT	0.85	0.85	AD05
Motor Rated Current, amp	RMC	5.3	5.3	AD05
Motor Rated Torque, N-m	RT	4.47	4.47	AD05
Motor Peak Torque, N-m	PRT	13.8	13.8	AD05
Preload Level (RT %)	PLD	10%	0%	DESIGN
Brake Reaction Time, sec	BRK_T	0.012	0.012	AD05
Brake Rating (Static), N-m	BRK_{STA}	6	6	AD05
Brake Rating (Dynamic), N-m	BRK_{DYN}	6	6	AD05
Motor Controller Rated Current, A	AMP_{RTD}	6	6	AD05
Motor Controller De-Rated Current, A	AMP_{DRTD}	4.4	4.4	CALC

4.4 Formulas

4.4.1 Motor Sizing Formulas

Following are the motor sizing formulas used for this analysis:

On-Axis Wind Torque, N-m $WIND_T = KWT * wind^2 * 1.06$

Structure Inertia Torque, N-m $TORQUE_{STR J} = J_{STR} * A * \Pi \text{ rad} / 180^\circ$

Resultant Axis Velocity, °/s $AXIS_{VEL} = RPM * 6 / N$

Structure Friction Torque, N-m $TORQUE_{STR FRIC} = F_{STR} + UB$

Motor Level Friction Torque (Motor, Brake, Gear-Box), N-m
 $TORQUE_{MTR FRIC} = F_{GB} + FV_{GB} * AXIS_{VEL} + F_{MTR}$

Motor Level Inertia Torque (Motor, Brake, Gear-Box), N-m
 $TORQUE_{MTR J} = [J_{MTR} + J_{BRK} + (IJ_{GB} / N_{GB}^2)] * N * A * \Pi / 180^\circ$

Motor Level Torque Due to Full Velocity (no acceleration), N-m
 $TORQUE_{FRIC} = [(WIND_T + TORQUE_{STR FRIC}) / (NM * N * E)] + TORQUE_{MTR FRIC}$

Motor Level Torque Due to Full Acceleration, N-m
 $TORQUE_{ACCEL} = TORQUE_{STR J} / (NM * N * E) + TORQUE_{MTR J}$

Motor Level Total Torque Required for Full Speed and Acceleration, N-m

$$TORQUE_{TOT} = TORQUE_{FRIC} + TORQUE_{ACCEL}$$

Motor Level Total Torque Required w/ Preload, N-m

$$TORQUE_{TOT + PLD} = TORQUE_{TOT} + PLD * RT$$

Maximum Motor Level Torque

$$TORQUE_{MAX} = \text{Current Limit Setting} * KT$$

4.4.2 Brake Sizing Formulas

Following are the brake sizing formulas used for this analysis:

Total On-axis Friction Torque $TORQUE_{FRIC TOT} = TORQUE_{FRIC} * NM * N$

Total On-Axis Inertia Torque $TORQUE_{ACCEL TOT} = TORQUE_{ACCEL} * NM * N * E$

On-Axis Brake Capacity $DYNBRK_{CAP} = BRK_{DYN} * NM * N$

Total On-Axis Brake Capacity $DYNBRK_{CAP\ TOT} = DYNBRK_{CAP} + TORQUE_{FRIC\ TOT}$

Torque Required to hold in Wind $WINDBRK = (WIND_T) * E / NM / N$

Deceleration Due to Setting Brake $STOP_{BRK} = (DYNBRK_{CAP\ TOT} / TORQUE_{ACCEL\ TOT}) * A$

Time to Stop After setting Brakes $TIME_{STOP} = AXIS_{VEL} / STOP_{BRK} + BRK_T$

Distance Travelled After Setting Brakes $DIS_{TRV} = 0.5 * STOP_{BRK} * TIME_{STOP}^2$

Total Brake Holding Requirement, Static, N-m $BRK_{STA\ REQ} = TORQUE_{MAX} + WINDBRK$

4.5 RESULTS

4.5.1 Azimuth Motor Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
On-Axis Wind Torque, N-m	$WIND_T$	@ 1 m/s 15.75 @ 9 m/s 1276	
Resultant Axis Velocity, °/s	$AXIS_{VEL}$	2.04	2.0
Torque due to Full Vel, N-m	$TORQUE_{FRIC}$	@ 1 m/s 0.45 @ 9 m/s 0.47	
Torque due to Full Accel, N-m	$TORQUE_{ACCEL}$	2.06	
Torque due to Full Vel and Accel, N-m	$TORQUE_{TOT}$	@ 1 m/s 2.50 @ 9 m/s 2.53	
Torque due to Full Vel and Accel + 25 % Preload, N-m	$TORQUE_{TOT + PLD}$	@ 1 m/s 6.75 @ 9 m/s 6.78	
Amplifier Derated Capacity, N-m	DRTD	13.8	
Overhead Capacity, %		@ 1 m/s 104 % @ 9 m/s 104 %	

4.5.2 Azimuth Brake Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
Total On-Axis Friction T, N-m	TORQUE _{FRIC TOT}	@ 1m/s 26,322 @ 9m/s 27,932	
Total On-Axis Accel T, N-m	TORQUE _{ACCEL TOT}	94,977	
On-Axis Brake Capacity, N-m	DYNBRK _{CAP}	1,298,026	
Total On-Axis Brk Capacity, N-m	DYNBRK _{CAP TOT}	1,324,349	
Decel due to Setting Brake, °/s ²	STOP _{BRK}	13.9	4°/s ² to 60°/s ²
Time to Stop after Setting Brake, s	TIME _{STOP}	0.19	
Distance Travelled after Setting Brake, °	DIS _{TRV}	0.26	
Torque Required to hold in Wind (36 m/s), N-m	WINDBRK	0.27	
Maximum Motor Torque (@Current Limit Setting), N-m	TORQUE _{MAX}	7.5	
Total Brake Static Holding Requirement, N-m	BRK _{STA REQ}	7.77	
		YES	BRK _{STA REQ} < BRK _{STA}

4.5.3 Altitude Motor Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
On-Axis Wind Torque, N-m	WIND _T	@ 1 m/s 16.99 @ 9 m/s 1376	
Resultant Axis Velocity, °/s	AXIS _{VEL}	2.0	2.0
Torque due to Full Vel, N-m	TORQUE _{FRIC}	@ 1 m/s 420 @ 9 m/s 1100	
Torque due to Full Accel, N-m	TORQUE _{ACCEL}	1,702	
Torque due to Full Vel and Accel, N-m	TORQUE _{TOT}	@ 1 m/s 2,122 @ 9 m/s 2,802	
Amplifier Derated Capacity, N-m	DRTD	3,504	
Overhead Capacity, %		@ 1 m/s 65 % @ 9 m/s 25 %	

4.5.4 Altitude Brake Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
Total on-axis friction T, N-m	TORQUE _{FRIC TOT}	@ 1m/s 840 @ 9 m/s 2,200	
Total On-Axis Accel T, N-m	TORQUE _{ACCEL TOT}	3,404	
On-Axis Brake Capacity, N-m	DYNBRK _{CAP}	19,220	
Total On-Axis Brk Capacity, N-m	DYNBRK _{CAP TOT}	@ 1 m/s 20,060 @ 9m/s 21,420	
Decel due to Setting Brake, °/s ²	STOP _{BRK}	10.81	8°/s ² to 60°/s ²
Time to Stop after Setting Brake, s	TIME _{STOP}	0.33	
Distance Travelled after Setting Brake, °	DIS _{TRV}	0.61	
Torque Required to hold in Wind (36 m/s), N-m	WINDBRK	11,010	
Maximum Motor Torque (@Current Limit Setting), N-m	TORQUE _{MAX}	3,264	
Total Brake Static Holding Requirement, N-m	BRK _{STA REQ}	14,275	
		YES	BRK _{STA REQ} < BRK _{STA}

4.5.5 Cassegrain Motor Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
On-Axis Wind Torque, N-m	WIND _T	@ 1 m/s 0.04 @ 9 m/s 3.26	
Resultant Axis Velocity, °/s	AXIS _{VEL}	3.7	3.6
Torque due to Full Vel, N-m	TORQUE _{FRIC}	@ 1 m/s 0.39 @ 9 m/s 0.39	
Torque due to Full Accel, N-m	TORQUE _{ACCEL}	0.32	
Torque due to Full Vel and Accel, N-m	TORQUE _{TOT}	@ 1 m/s 0.72 @ 9 m/s 0.72	
Torque due to Full Vel and Accel + Preload, N-m	TORQUE _{TOT +PLD}	@ 1 m/s 1.16 @ 9 m/s 1.16	
Amplifier Derated Capacity, N-m	DRTD	3.74	
Overhead Capacity, %		@ 1 m/s 221% @ 9 m/s 221%	100%

4.5.6 Cassegrain Brake Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
Total On-Axis Fiction T, N-m	TORQUE _{FRIC TOT}	@ 1m/s 4,607 @ 9 m/s 4,611	
Total On-Axis Accel T, N-m	TORQUE _{ACCEL TOT}	3,272	
On-Axis Capacity, N-m	DYNBRK _{CAP}	70,200	
Total On-Axis Brk Capacity, N-m	DYNBRK _{CAP TOT}	@ 1 m/s 74,807 @ 9m/s 74,811	
Decel due to Setting Brake, °/s ²	STOP _{BRK}	57.16	16°/s² to 120°/s²
Time to Stop after Setting Brake, s	TIME _{STOP}	0.07	
Distance Travelled after Setting Brake, °	DIS _{TRV}	0.16	
Torque Required to hold in Wind (36 m/s), N-m	WINDBRK	0.00	
Maximum Motor Torque (@Current Limit setting), N-m	TORQUE _{MAX}	2.16	
Total Brake Static Holding Requirement, N-m	BRK _{STA REQ}	2.27	
		YES	BRK_{STA REQ} < BRK_{STA}

4.5.7 Cassegrain Cablewrap Motor Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
On-Axis Wind Torque, N-m	WIND _T	@ 1 m/s 0.04 @ 9 m/s 3.26	
Resultant Axis Velocity, °/s	AXIS _{VEL}	5.75	3.6
Torque due to Full Vel, N-m	TORQUE _{FRIC}	@ 1 m/s 0.65 @ 9 m/s 0.65	
Torque due to Full Accel, N-m	TORQUE _{ACCEL}	0.21	
Torque due to Full Vel and Accel, N-m	TORQUE _{TOT}	@ 1 m/s 0.86 @ 9 m/s 0.86	
Torque due to Full Vel and Accel + Preload, N-m	TORQUE _{TOT +PLD}	@ 1 m/s 0.86 @ 9 m/s 0.86	
Amplifier Derated Capacity, N-m	DRTD	3.74	
Overhead Capacity, %		@ 1 m/s 334% @ 9 m/s 333%	100%

4.5.8 Cassegrain Cablewrap Brake Sizing Results

Below are the results of the calculations performed:

DESCRIPTION	TERM	RESULT	SPEC
Total On-Axis Fiction T, N-m	$TORQUE_{FRIC\ TOT}$	@ 1m/s 2,440 @ 9 m/s 2,443	
Total On-Axis Accel T, N-m	$TORQUE_{ACCEL\ TOT}$	737	
On-Axis Capacity, N-m	$DYNBRK_{CAP}$	22,542	
Total On-Axis Brk Capacity, N-m	$DYNBRK_{CAP\ TOT}$	@ 1 m/s 24,982 @ 9m/s 24,985	
Decel due to Setting Brake, $^{\circ}/s^2$	$STOP_{BRK}$	85	$16^{\circ}/s^2$ to $120^{\circ}/s^2$
Time to Stop after Setting Brake, s	$TIME_{STOP}$	0.05	
Distance Travelled after Setting Brake, $^{\circ}$	DIS_{TRV}	0.13	
Torque Required to hold in Wind (36 m/s), N-m	$WINDBRK$	0.01	
Maximum Motor Torque (@ Current Limit Setting), N-m	$TORQUE_{MAX}$	1.47	
Total Brake Static Holding Requirement, N-m	$BRK_{STA\ REQ}$	1.48	
		YES	$BRK_{STA\ REQ} < BRK_{STA}$

4.6 Conclusions

The result of this Motor and Brake Sizing Analysis report shows that the Cassegrain 100% overhead motor torque margin is exceeded. The Azimuth axis shows overhead margins of approximately the same amount, while the Altitude axis shows lower overhead values. Based on the above results, and with consideration to the Drive Analysis Report, AD04, the following current (torque) limit settings will be set on the motor controllers:

Azimuth	11.9 A = 7.5 N-m
Altitude	20.4 A = 3,269 N-m
Cassegrain	2.67A = 2.27 N-m
CASS CableWrap	1.73 A = 1.47 N-m

Azimuth, Altitude and Cassegrain Rotator axis shows that the brake decelerations are within the specified range.

The Azimuth, Altitude and Cassegrain brake's static holding capacity exceeds the maximum motor torque combined with survival wind loading.

__oOo__