NEWFIRM

SYSTEM DESIGN NOTE

Title: NFM-AD-02-1401 Some remarks on precision and NEWFIRM design					
Prepared by	**Date**	**Approved by**	**Date**	**Rev.**	**Rev Date**
R. Probst	2/4/03				
Related documents:					

Summary/Description: (attach additional sheets as required)
The purpose of this informational note is to assist our thinking about the mechanical design of NEWFIRM as regards achievable precision (or level of uncertainty) and how the mechanical error budget should be assigned between input values (CTE, temperature), design, fabrication, and assembly.

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Introduction

The purpose of this informational note is to assist our thinking about the mechanical design of NEWFIRM as regards achievable precision (or level of uncertainty) and how the mechanical error budget should be assigned between input values (CTE, temperature), design, fabrication, and assembly. This is driven primarily by the question of how uncertainties in CTE should affect materials choices and mechanical design. There are also implications for how tightly temperatures may need to be controlled.

All dimensions will be given in inches and, where useful, (millimeters).

1. Input data

1.1 Initial optical tolerances:

despace (longitudinal)	±0.002 – 0.008	± (0.050 – 0.200)
decenter (transverse)	±0.0008 – 0.002	±(0.020 – 0.050)

As Ming has noted, these are likely to be relaxed in various ways, and/or dealt with via active alignment adjustments subsequent to assembly. For any single part these are worst case.

1.2 Typical machining tolerances:

part diameter or linear dimension	±0.0002 achievable ±0.0005 comfortable
pin location for parts positioning	±0.0002
perpendicularity, side to base	±0.0002 achievable ±0.0005 comfortable
parallelism, faces on either end	±0.0001
surface roughness, each face	±0.0002
concentricity, hole in circular part	±0.0005
depth, hole in part	±0.0005
fabrication temperature of part	±1 ºF (0.5 ºC or K)

These are for parts dimension about 8 inches length or diameter, per Roger Repp.

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1.3 Achievable levels of precision in the determination of CTE, per Jay Elias:

± 2 % values from literature, handbook tabulations, etc. for given material

± 1 % CTE measurement for specific piece of material to be used in fabrication (the offset from a handbook value may be larger)

± 0.5 % relative precision, e.g. between CTE's measured for two pieces of material by a precision measurement firm

1.4 Typical NEWFIRM values:

5 inches (125 mm) typical lens diameter

15 inches (375 mm) largest lens diameter; barrel length for camera section

30 inches (750 mm) spacing between collimator groups

193 K temperature drop from fabrication to working temperature, 293 K to 100 K; worst case, working temperature may be 50 K to 100 K higher depending on thermal design and part location

2. Formulae

2.1 Change Δl in part dimension l from mean coefficient of thermal expansion CTE over temperature range ΔT :

$$\Delta l = l \times CTE \times \Delta T$$

2.2 Level of precision δl in cold part dimension from precision to which CTE is known, δ(CTE) ; or variation in final temperature, δT:

$$\delta l = \Delta l \times \delta(CTE) \; ; \quad \delta l = \Delta l \times \delta T$$

3. A pro forma tabulation

The following table gives δl for various materials over a 193 K drop, for either 1% precision in CTE or a 1% variation (1.9 K) in final temperature. Results may be compared with optical tolerance requirements and achievable machining precisions noted above. For parts with CTE taken from handbook values, double these results. All values are ± from calculated Δl , so double them to get the total range end-to-end.

Table 1. Uncertainty δl in parts dimension for CTE or final temperature known to 1%, over the range 293 K to 100 K.

Material	CTE, ppm	Part dimension, inches (mm)		
		30 (750)	15 (375)	5 (125)

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Aluminum 6061T651	18.45 (1)	0.0011	0.0005	0.0002
Stainless steel Type 302	13.47 (1)	0.0008	0.0004	0.0001
Steel Type 1075	8.78 (1)	0.0005	0.0003	0.00008
Titanium	6.94 (2)	0.0004	0.0002	0.00007
Invar	0.24 (2)	0.00001	< 0.00001	< 0.00001
IR fused silica	0.00 (2)	---	0.00	0.00
ZnSe	5.85 (2)	---	---	0.00006
Ca F_2	13.90 (1)	---	0.0004	0.0001

(1) data from GNIRS System Design Notes tabulation of CTE values by Jay Elias
(2) data from R. Blakley's NEWFIRM design note on temperature compensated lens cells

Table values can be scaled for parts dimensions, larger uncertainty in CTE, larger variation in working temperature T, or reduced range of temperature drop from fabrication to working temperature. In the last case these values become approximate since the table uses mean CTE over the range 293 – 100 K. The mean over a different range can be different.

My overall summary is that we have a reasonable parameter space to work in regarding materials choices, temperature range, and allocation of the error budget between optics, design, fabrication, assembly, and uncertainties in numerical values.