Sinclair Interplanetary

RYERSON UNIVERSITY

Custom Optics vs Modified COTS for Small Spacecraft : The Build vs Rebuild Decision

or

A Case Study in Applied Hubris

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Summary

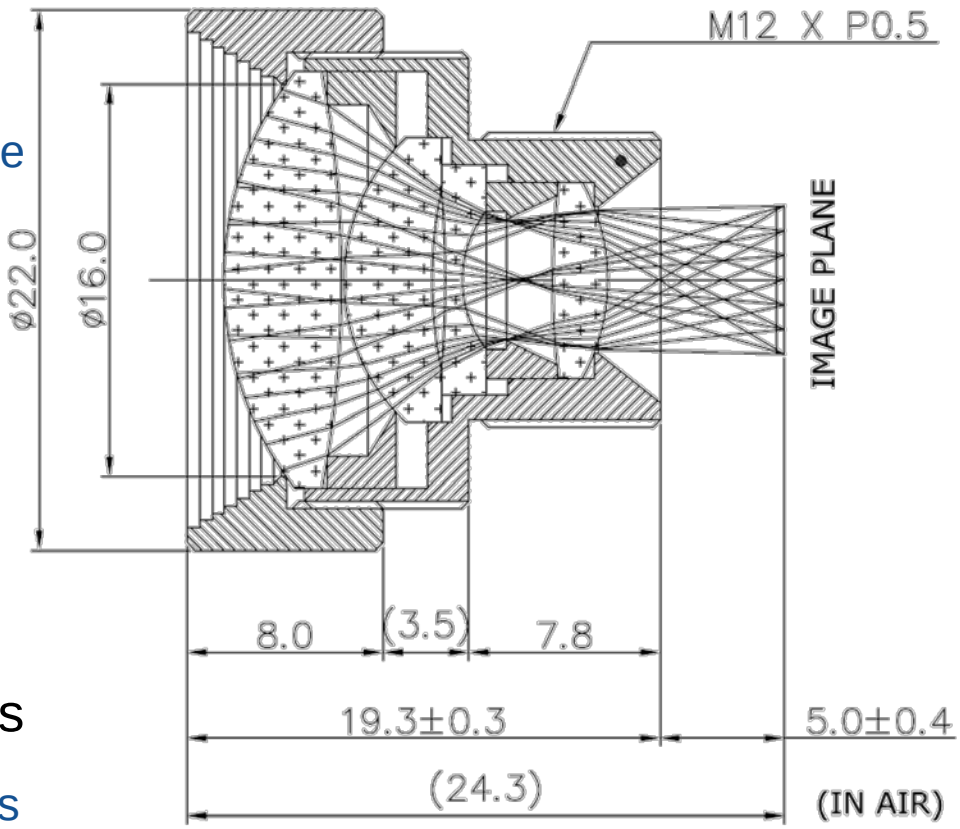
- Original commercial lens
- Its shortcomings
- Our first custom lens
- Its advantages
- Its shortcomings
- Our second custom lens
- Conclusion

Original Commercial Lens

Lens Datasheet Specifications	
Vendor	Marshall Electronics
Part Number	V-4416.0-1.2-HR
Focal Length	16 mm
f-number	f/1.2
Intended Market	Security cameras Machine vision
Prior Space Heritage	“Used on Mars” Unable to verify claim

Commercial Lens General Shortcomings

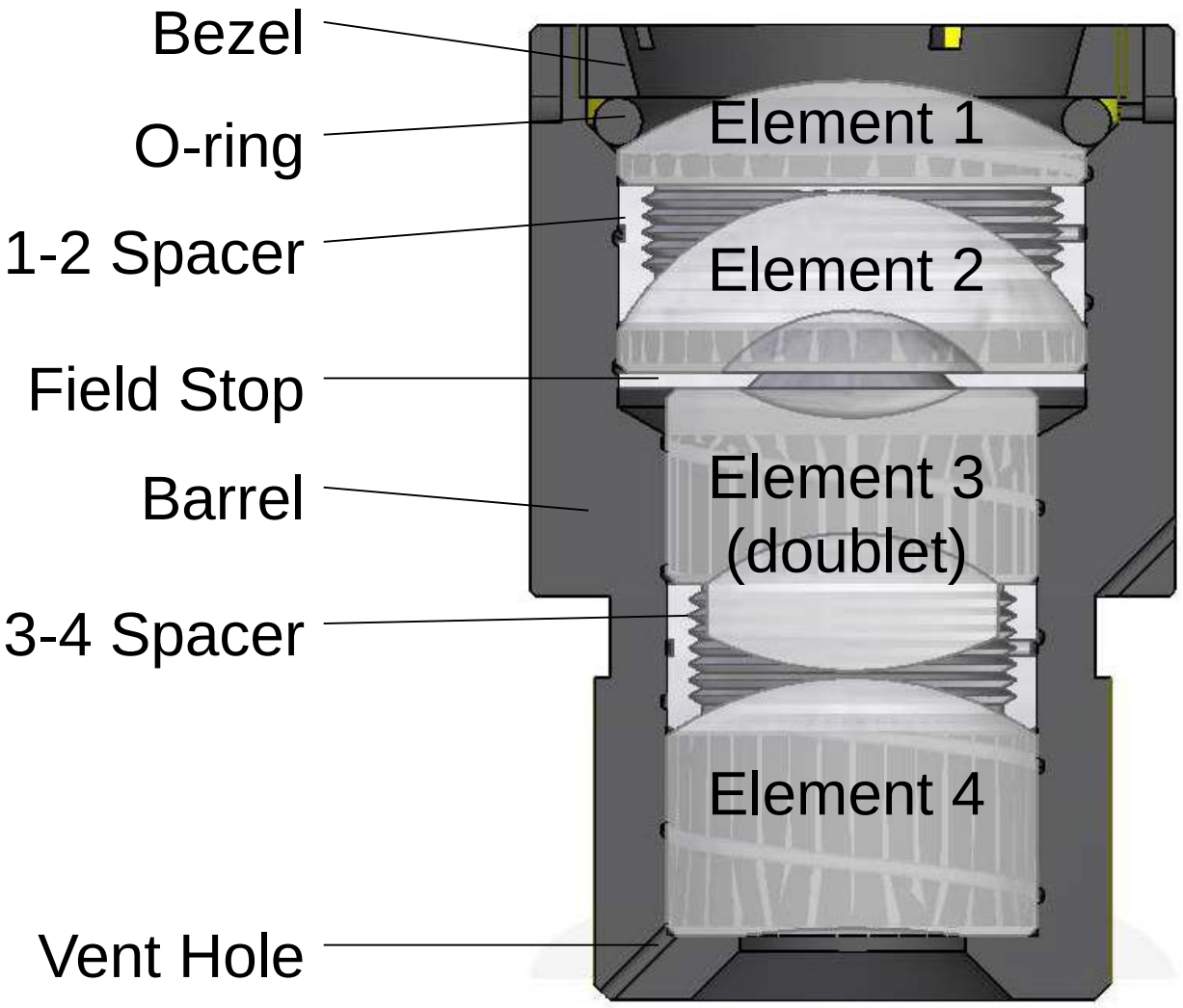
- Black anodized surface
  - Impossible to make electrical ground
- Aluminum expands faster than glass
  - Preload vanishes at high temperature
- Many lenses have zero preload from factory
  - Front glass can be rotated by hand
- Trapped air pockets
  - Venting is not assured
- No model available
  - Cannot perform optical simulations
- Poor match to detector microlenses
  - Significant loss of sensitivity at edges of FoV



Commercial Lens F-number Discrepancy

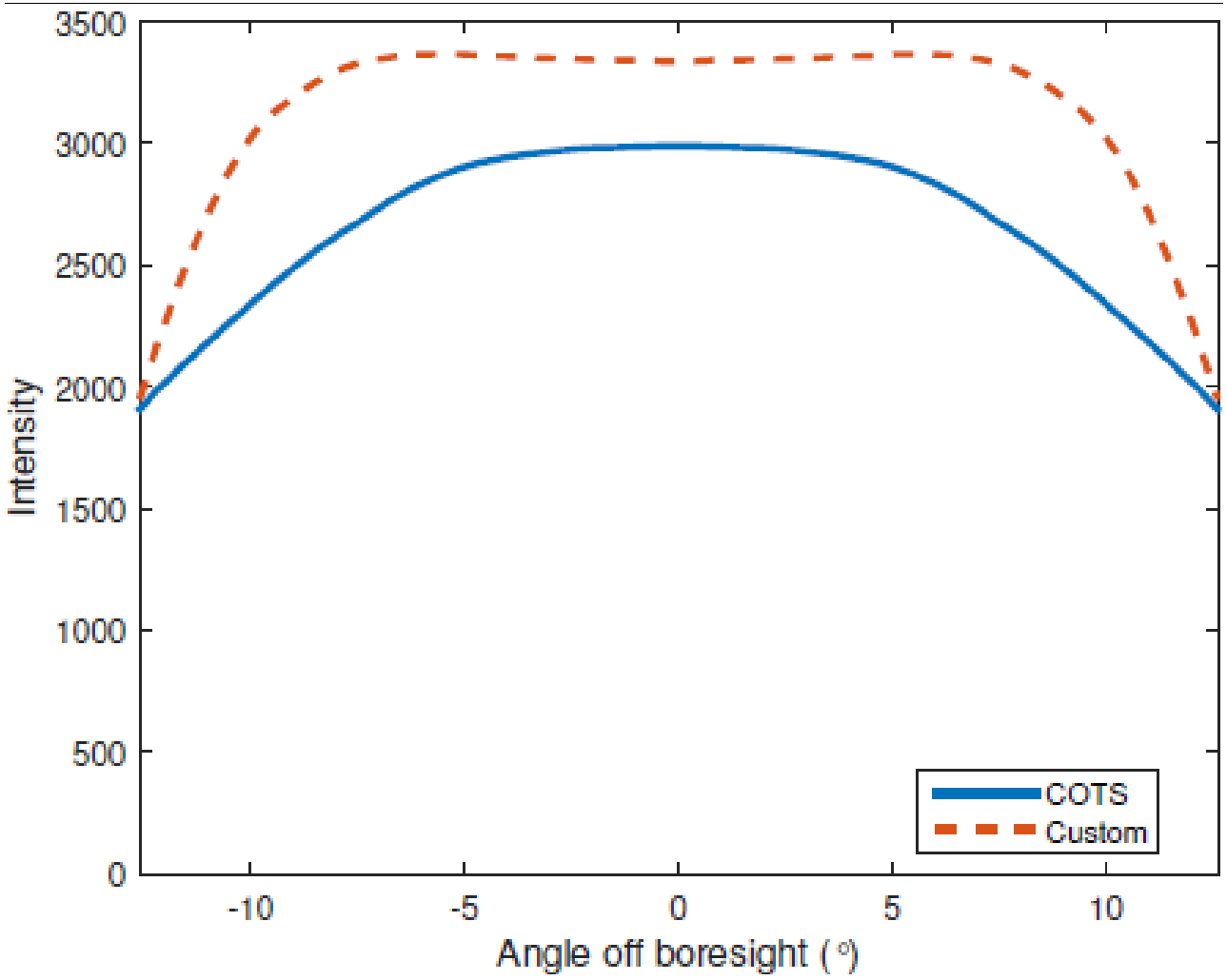
- Entrance pupil directly imaged
- $f/_{\#} = \frac{9.52\ mm}{16\ mm} = f/_{1.68}$ (actual)
- $f/_{1.2}$(datasheet)
- Lens vendor unwilling to explain discrepancy
- Caveat emptor!

The 1st Custom Lens: ST-16RT



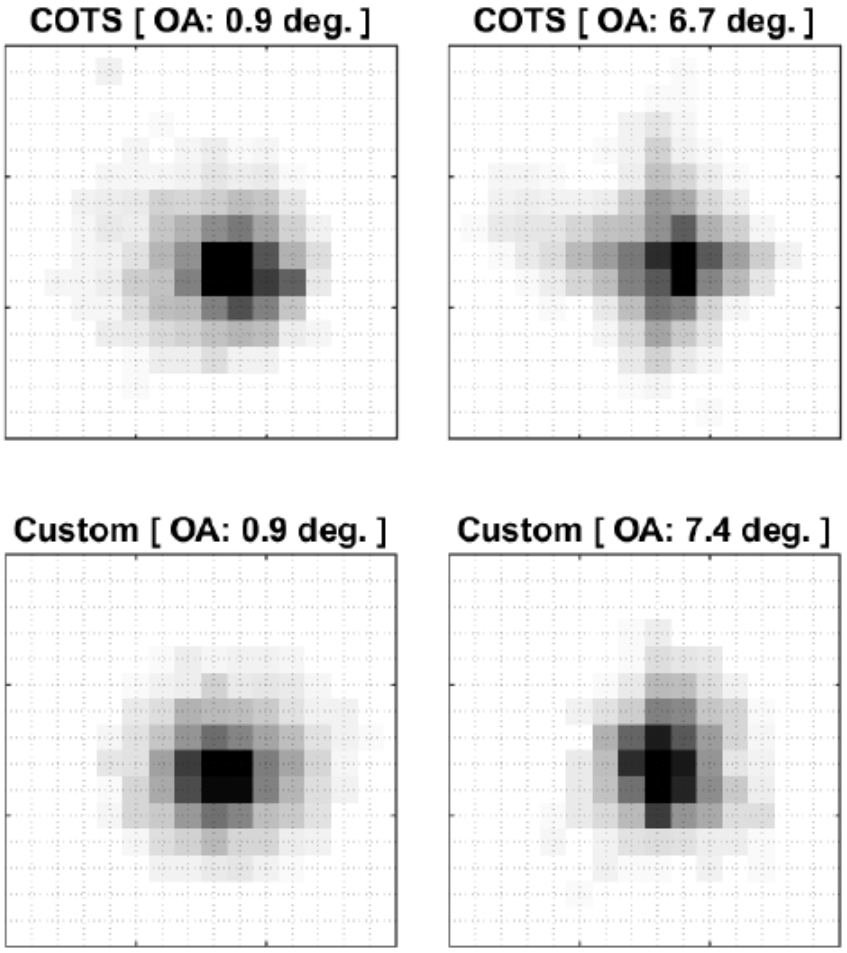
- 16 mm focal length
- f/1.6
- Conductive mating surfaces
- O-ring ensures preload over temperature
- Venting path for all air pockets
- Achromatic doublet

Photometric Performance



- Custom lens admits more light
- Custom lens has wider FoV without vignetting

Relative Resolution



Spot Radius

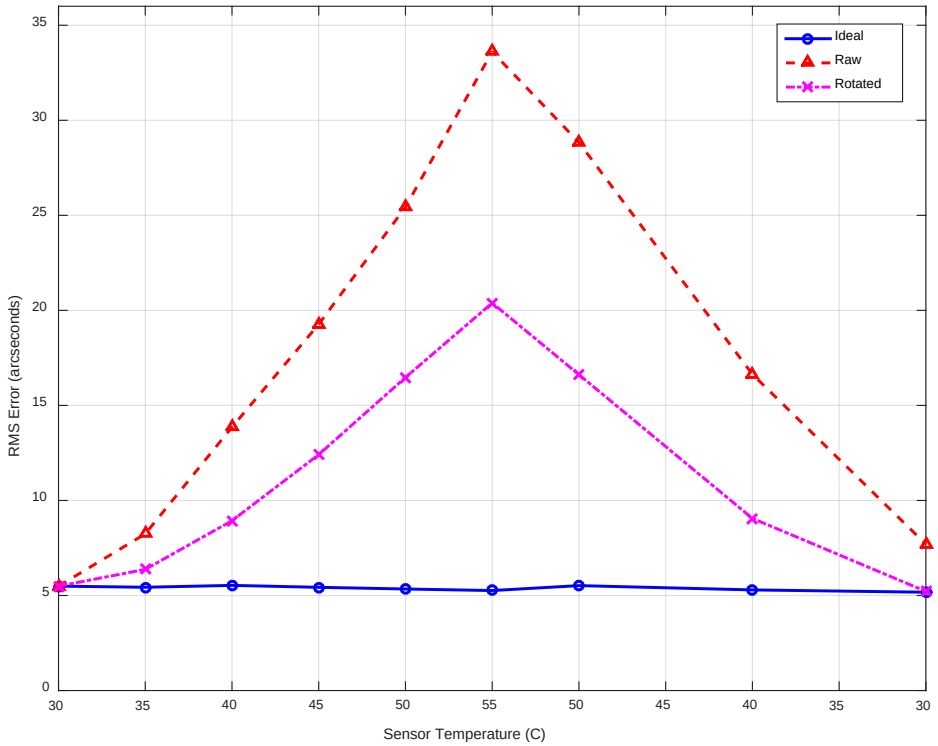
Off-Axis Angle	COTS	Custom
1	5.04	4.32
4	5.03	4.59
7	5.84	4.18

(in pixels, 85% Encircled Power)

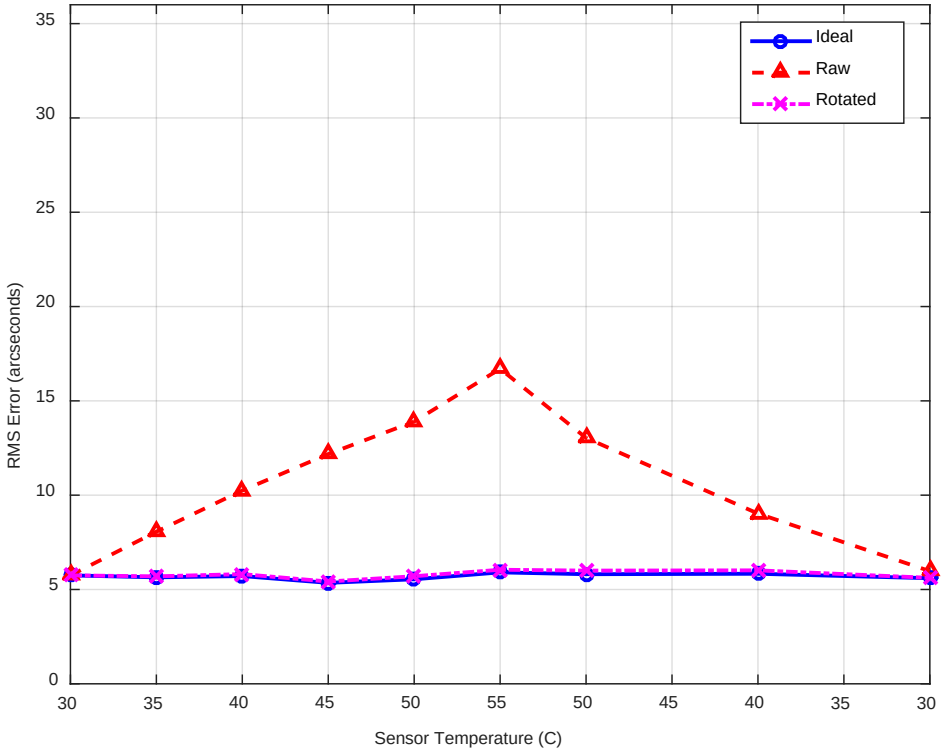
Custom lens has higher resolving power

Relative Thermal Stability

COTS

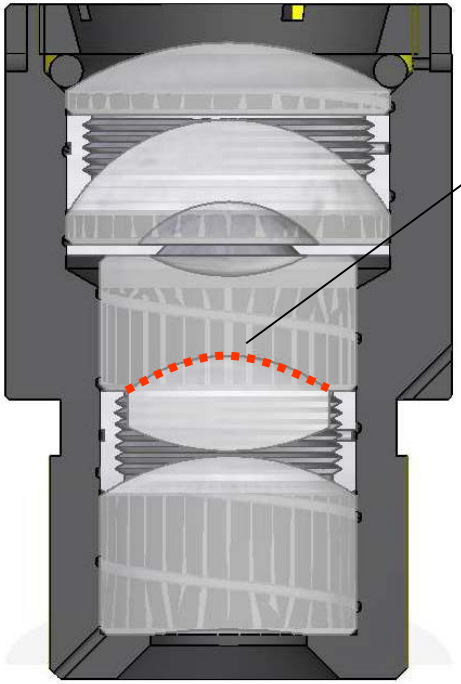


Custom

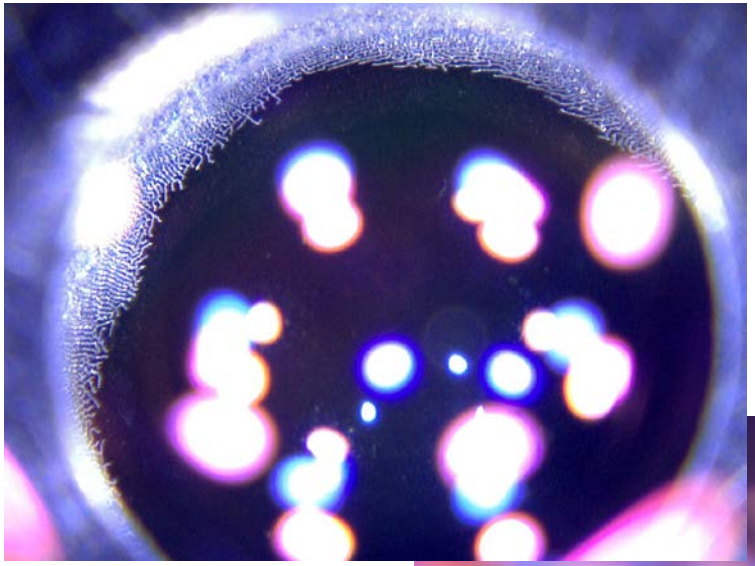


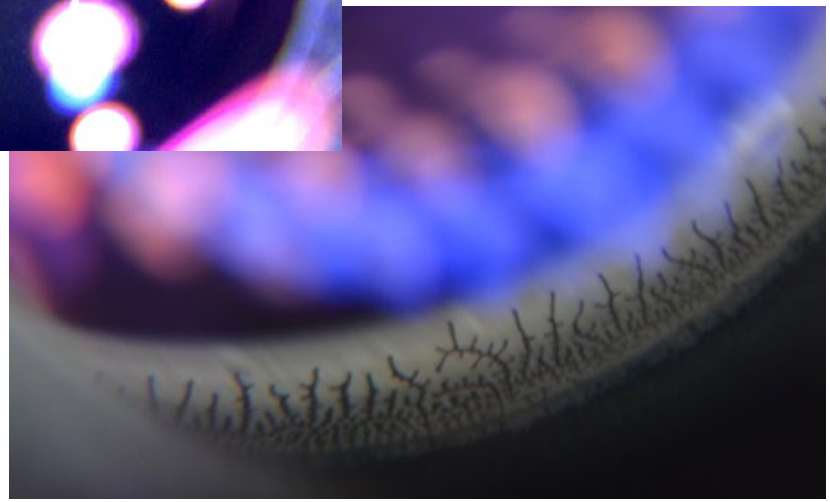
Custom lens has far better stability over temperature

… And it all goes horribly wrong



Optical cement in achromatic doublet cracks over long-term temperature





The Second Custom Lens: ST-16RT2

- Doublet materials changed to match CTEs.
- Design tuned for:
  - Shorter length
  - Reduced chromatic aberration
  - Better photometric efficiency
  - Wider unvignetted field
- First prototypes assembled mid-August.

Conclusion

- Commercial lenses may have undesirable characteristics
- Validate all datasheet claims before use
- Custom lenses have the potential to boost system performance
- Never run qualification campaign in parallel with flight manufacture
- Design error cost me:
  - $300k in scrap ST-16RT optics
  - 6+ month delay in $3M in deliveries