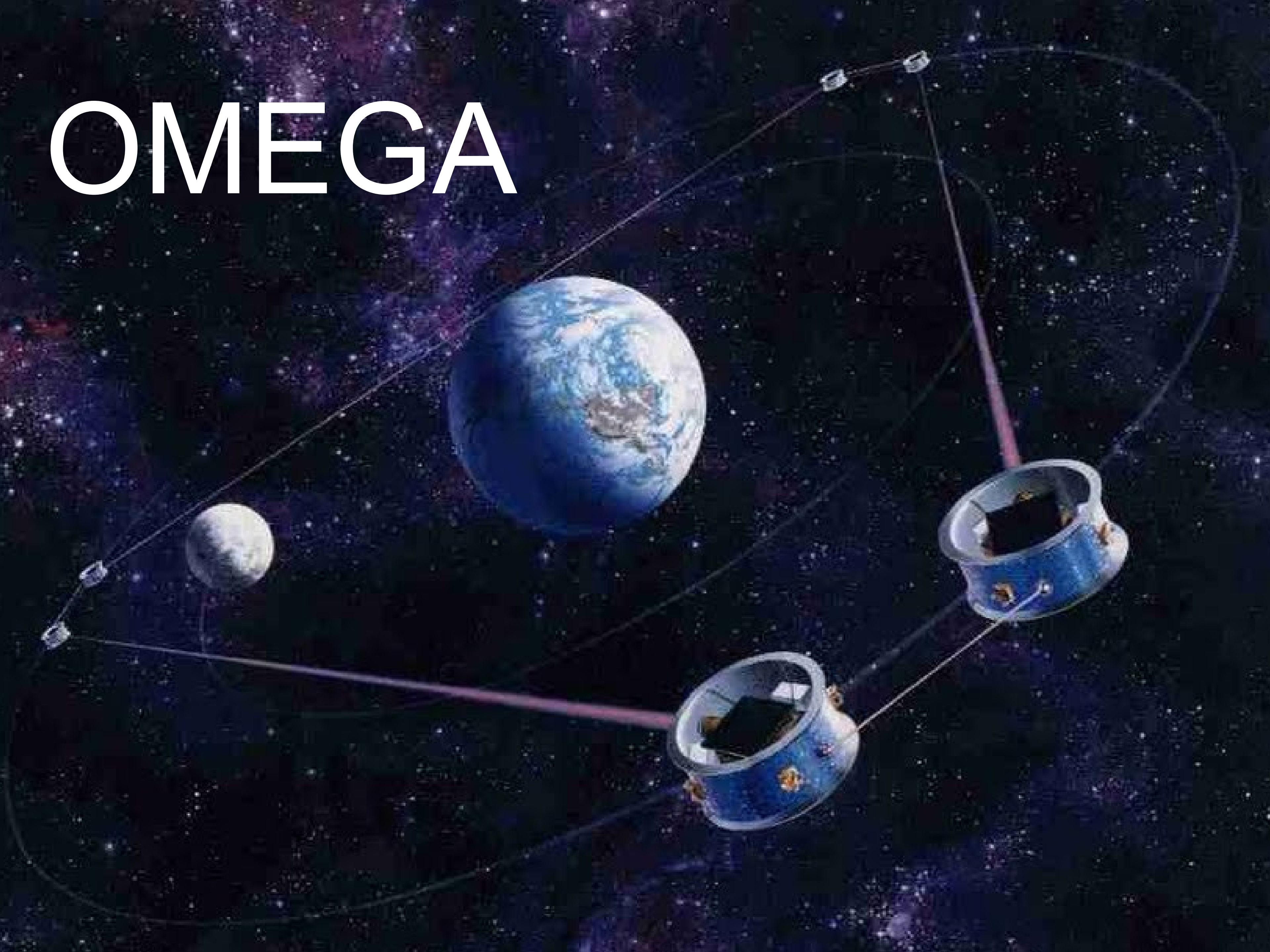
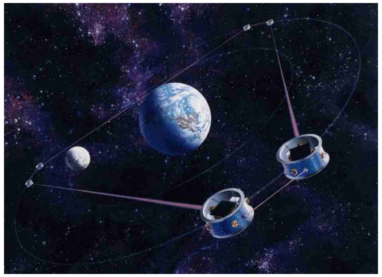
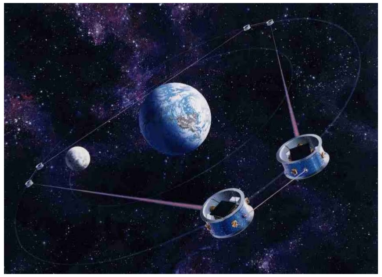
OMEGA



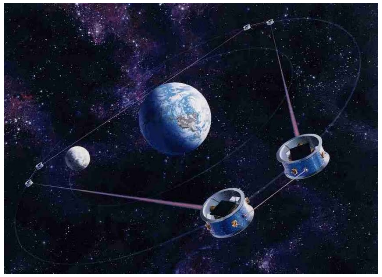


COST



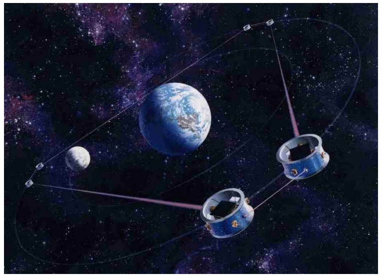
OMEGA Cost Rollups

WBS #	Activity	FY98 $M	
		Aerospace Parametric	JPL Grassroots
	Phase A	0.3	0.3
	Phase B	2.3	distributed
10000	Project management	5.1	5.9
20000	Science	8.6	9.8
30000	Project & Mission Eng.	8.7	5.5
40000	Instrument	25.0	25.0
50000	Spacecraft Bus	40.3	39.9
60000	ATLO	2.8	2.7
70000	Mission Operations	9.1	11.8
80000	Launch Vehicle	32.1	32.1
	Sub Total	133.8	133.0
90000	reserves	18.7	20.2
	TOTAL	152.6	153.2



OMEGA Cost Rollups

WBS #	Activity	FY12 $M	
		Aerospace Parametric	JPL Grassroots
	Phase A	0.4	0.4
	Phase B	3.2	distributed
10000	Project management	7.0	8.1
20000	Science	11.9	13.5
30000	Project & Mission Eng.	12.0	7.6
40000	Instrument	34.5	34.5
50000	Spacecraft Bus	55.6	55.0
60000	ATLO	3.9	3.7
70000	Mission Operations	12.5	16.3
80000	Launch Vehicle	44.3	44.3
	Sub Total	184.5	183.4
90000	reserves	25.8	27.9
	TOTAL	210.4	211.3



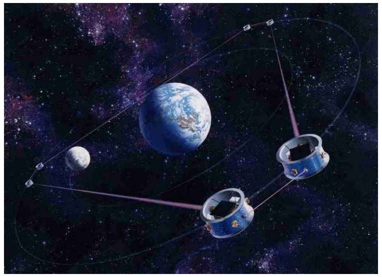
OMEGA MIDEX Costing History

- JPL non-advocate MIDEX cost review
- Second JPL non-advocate MIDEX cost review
- MIDEX TMCO cost analysis:

Delta II - $46M
SELVS II-B - $32M

"Exclusive of the launch vehicle cost problem, and assuming that the drag-free technology is proven by some other means such as ODIE, the OMEGA costs seem reasonable."

OMEGA Demonstration International Explorer



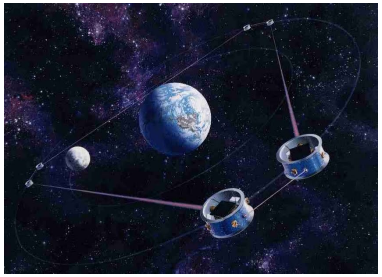
OMEGA MIDEX Costing

Uhuru GRE FUSE WMAP

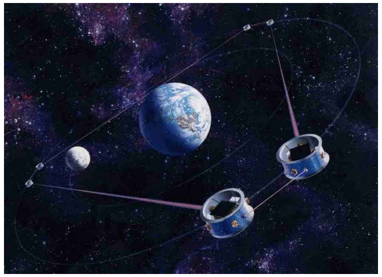
"reasonable" because there have been many successful explorer-class missions

COBE WISE Swift

The "normal" path to new astronomies in NASA begins with an explorer mission.



RISK



OMEGA Risk Analysis

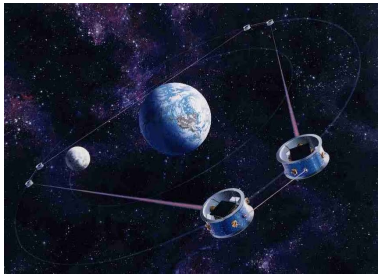
- No scientist wants to fly a mission that risks failure
- But missions sometimes fail even big expensive missions

Hubble Space Telescope

Galileo

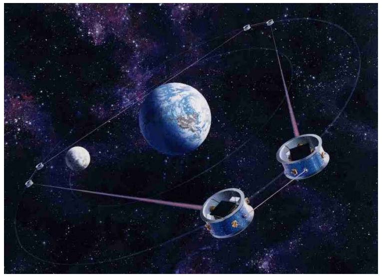
Mars Observer

- One hedge against mission failure is redundancy



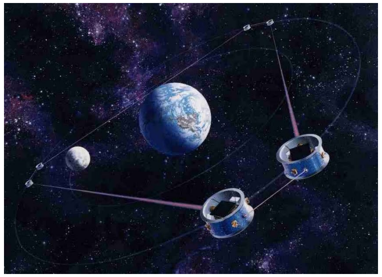
OMEGA Risk Analysis

Class	Parts	Redundancy	Incremental Cost
A			
C			



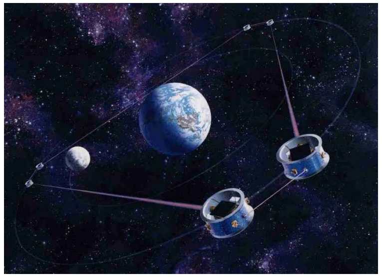
OMEGA Risk Analysis

Class	Parts	Redundancy	Incremental Cost
A	Space-qualified	No single-point failures	
C			



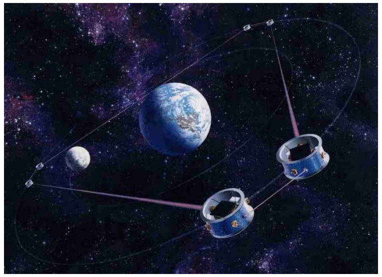
OMEGA Risk Analysis

Class	Parts	Redundancy	Incremental Cost
A	Space-qualified	No single-point failures	
C	Mil-spec, space-qualifiable	Selected redundancy	



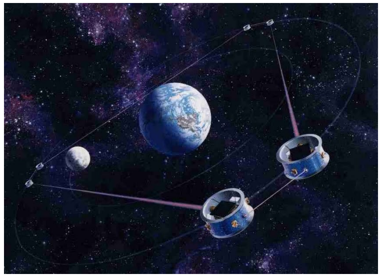
OMEGA Risk Analysis

Class	Parts	Redundancy	Incremental Cost
A	Space-qualified	No single-point failures	
C	Mil-spec, space-qualifiable	Selected redundancy	$1



OMEGA Risk Analysis

Class	Parts	Redundancy	Incremental Cost
A	Space-qualified	No single-point failures	\$2.50
C	Mil-spec, space-qualifiable	Selected redundancy	\$1

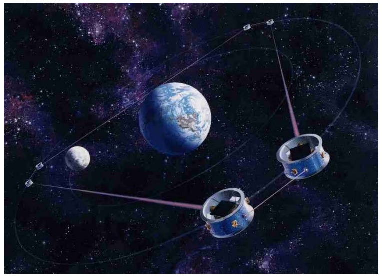


OMEGA Risk Analysis

- OMEGA has two probes at each vertex of the detector

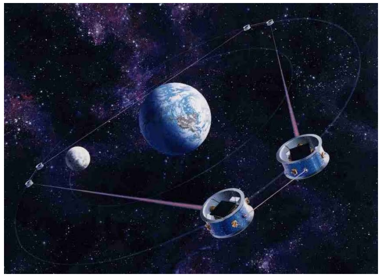
Failure type	3 Class A		6 Class C	
	Probes lost	Mission lost?	Probes lost	Mission lost?
Irrecoverable fatal design flaw	3	Yes	6	Yes
Recoverable fatal design flaw	1	Yes	1	No
Spacecraft-fatal random failure	1	Yes	1	No
Subsystem random failure	0	No	1	No

- OMEGA provides Class A mission reliability using Class C spacecraft

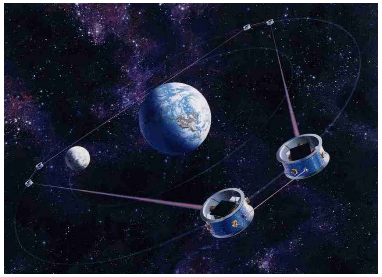


Why Six OMEGA Probes?

- Redundancy
- Cost:
  - one set of non-recurring engineering costs
  - standard discounts for multiple builds
- No major moving parts
- Continuous smooth pointing

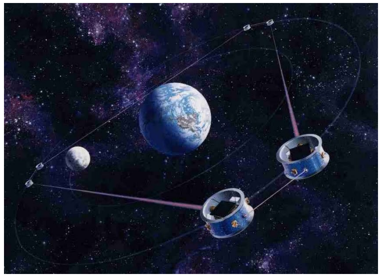


Orbit Stability



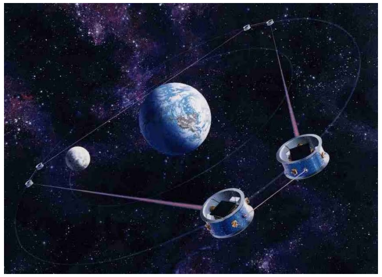
OMEGA Orbit Stability

- OMEGA orbits are long-term stable ⇒ Extended mission



OMEGA Orbit Stability

- OMEGA orbits are long-term stable ⇒ Extended mission
- Orbit analysis gives $\dot{L} \approx 53\,\mathrm{m/s} \;\Rightarrow\; \Delta\nu = \pm 50\ \mathrm{MHz}\ \ \mathrm{Doppler}$



OMEGA Orbit Stability

- OMEGA orbits are long-term stable ⇒ Extended mission
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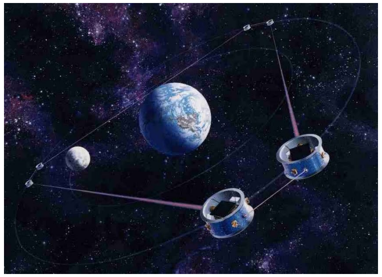
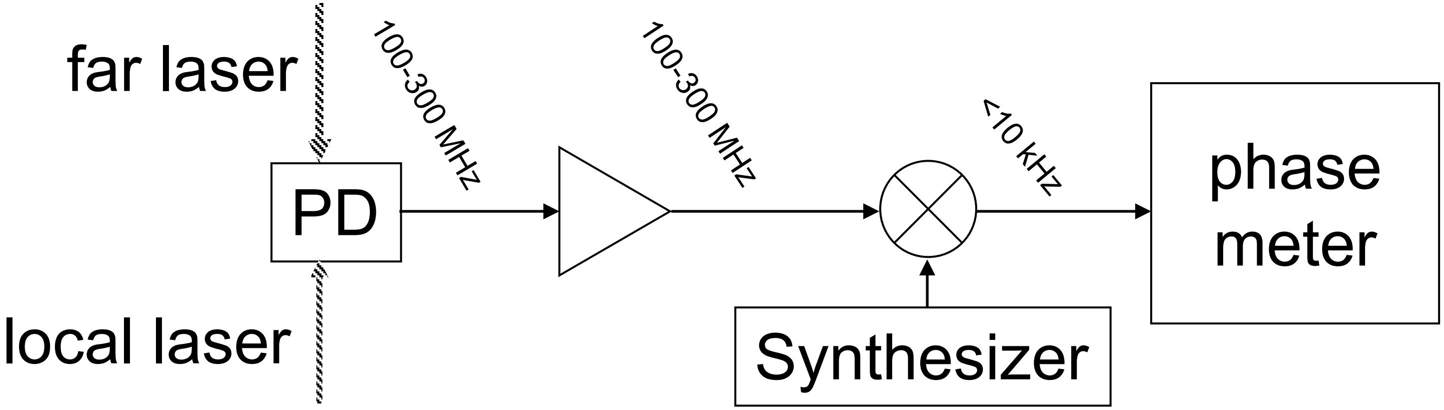
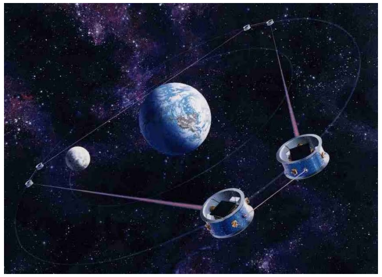
- So we design for it



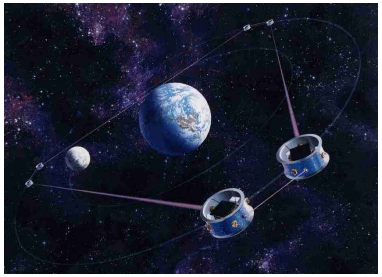
OMEGA Orbit Stability

- OMEGA orbits are long-term stable ⇒ Extended mission
- Orbit analysis gives $\dot{L} \,\square\, 53\,\mathrm{m/s} \;\Rightarrow\; \Delta\nu = \pm 50\ \mathrm{MHz}\ \ \mathrm{Doppler}$
- So we design for it



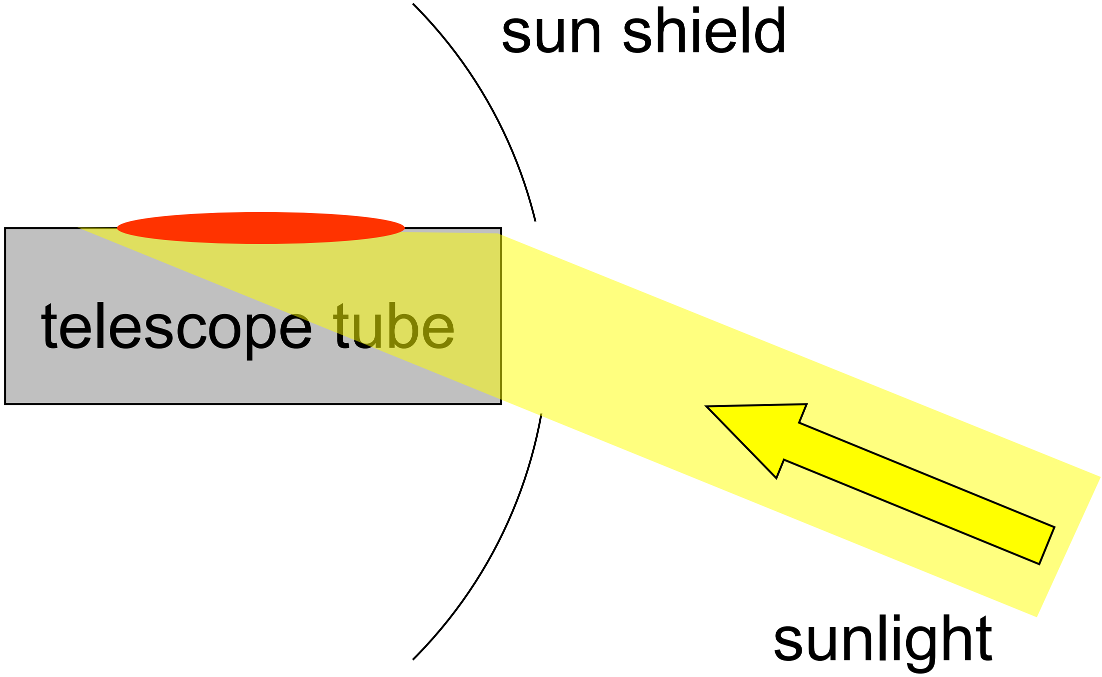


Sun
Filter



OMEGA Sun Filter

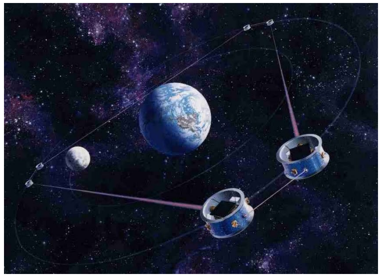
The problem



sun shield

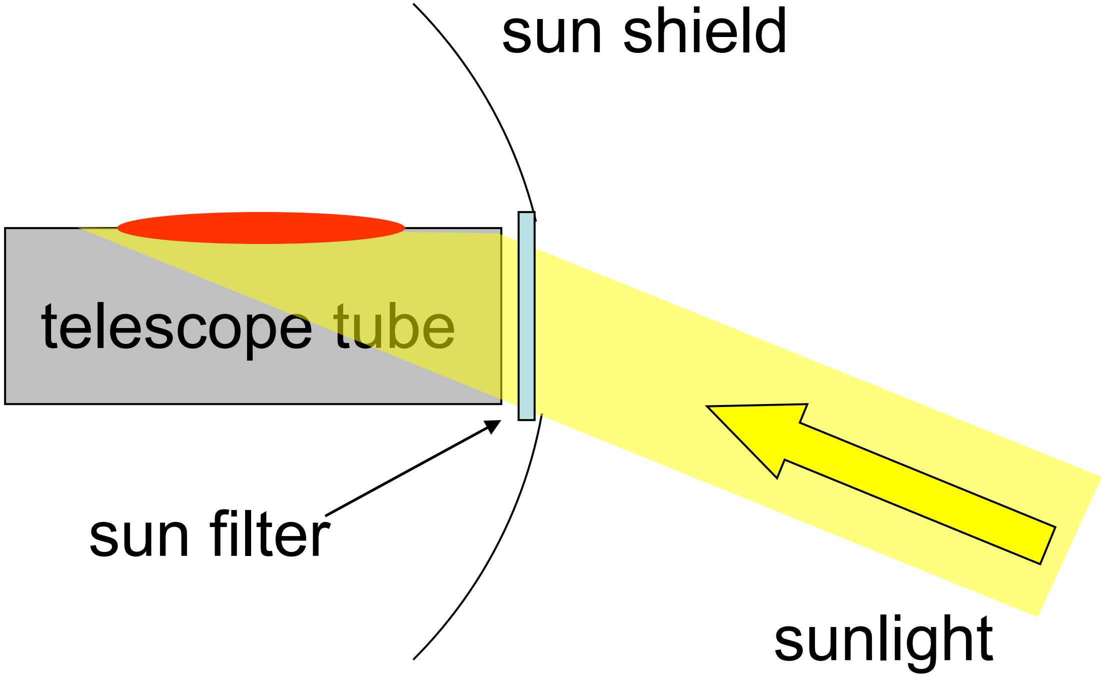
telescope tube

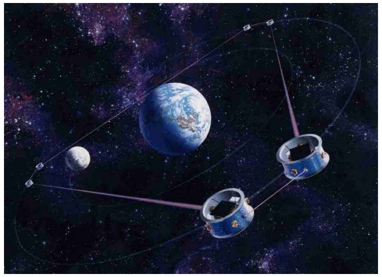
sunlight



OMEGA Sun Filter

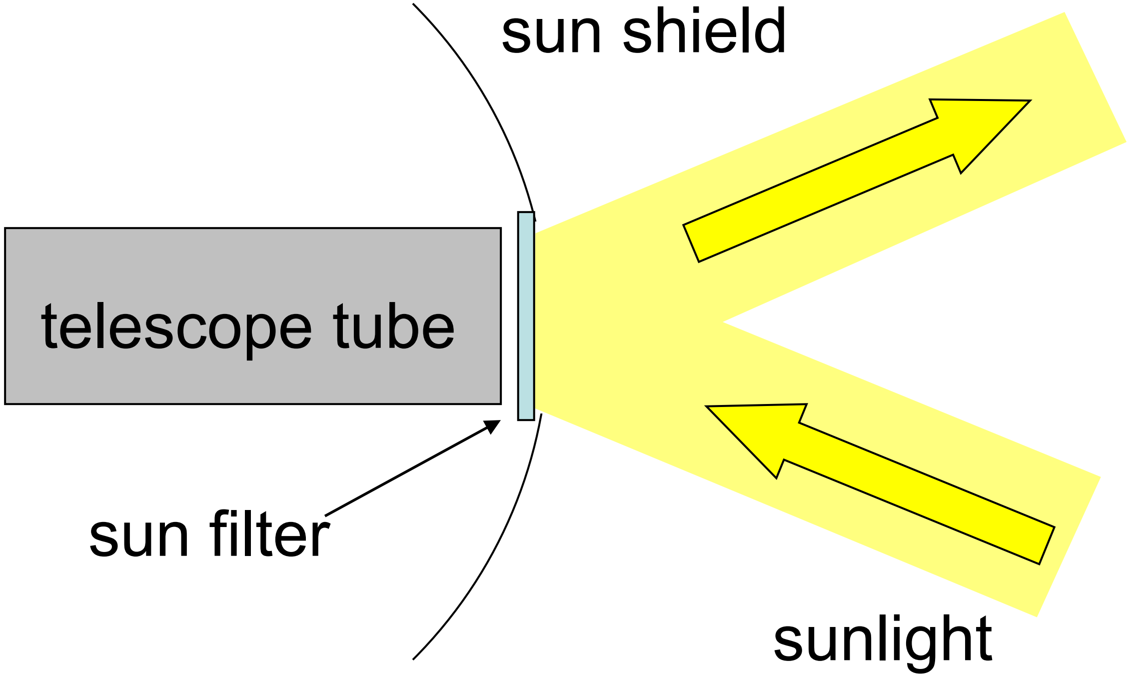
The problem

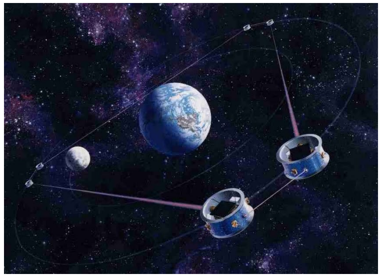




OMEGA Sun Filter

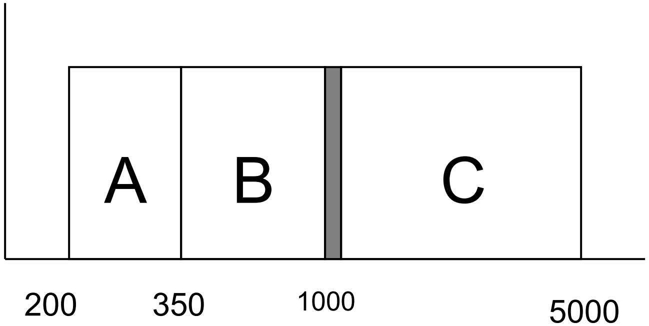
The problem

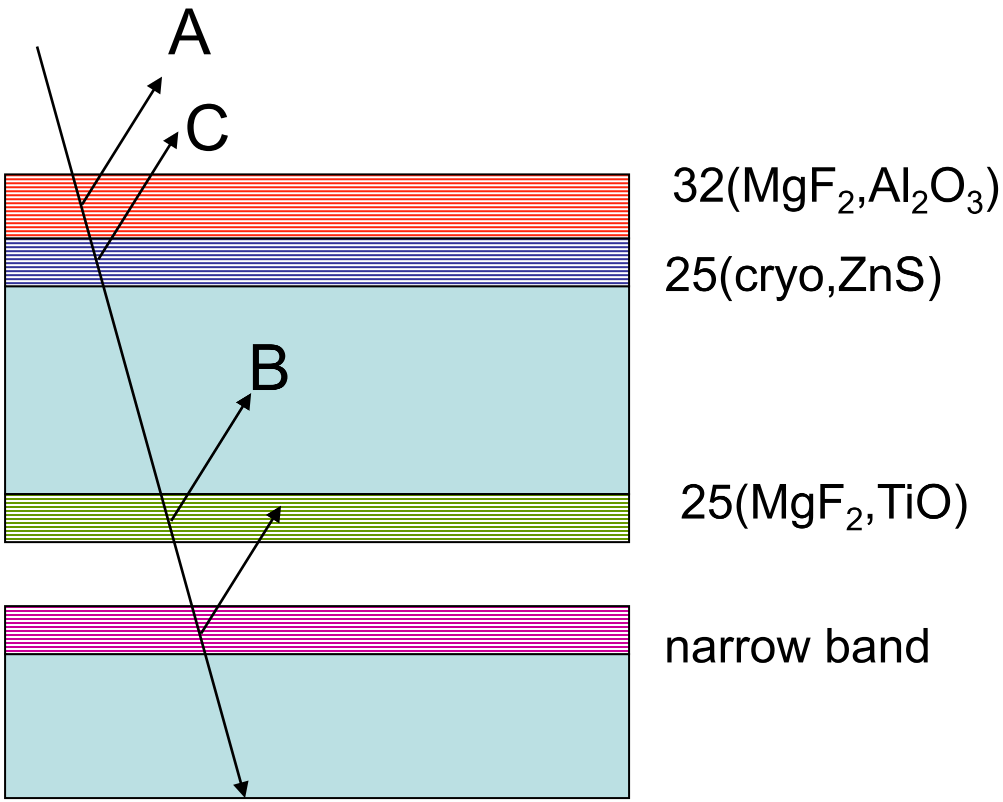


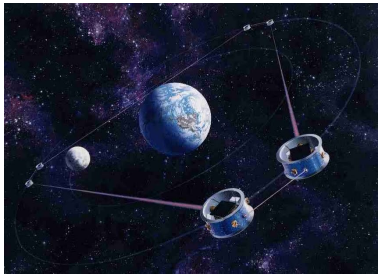


OMEGA Sun Filter

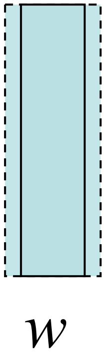
Goal: reflect 98% of total insolation / pass 1024±5 nm





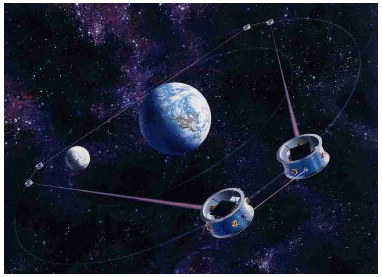


OMEGA Sun Filter
Path Noise



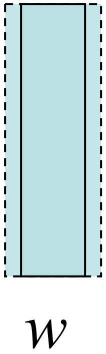
The change in optical path length is

$$\delta L = w[(n-1)dw/dT + dn/dT]\delta T \equiv wG\delta T$$



OMEGA Sun Filter

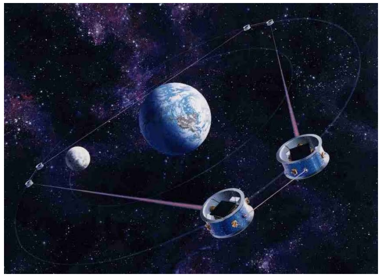
Path Noise



The change in optical path length is

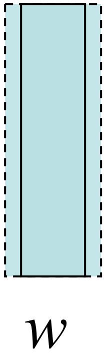
$$\delta L = w[(n-1)dw/dT + dn/dT]\delta T \equiv wG\delta T$$

We use a glass (*e.g.*, Schott AK51) with $G = \pm(2)\times 10^{-7}$



OMEGA Sun Filter

Path Noise



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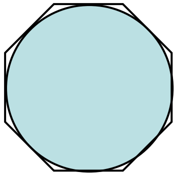
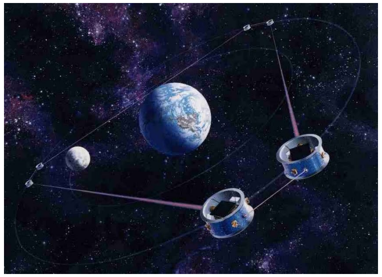


We isolate the filter so that its temperature is determined by insolation balance only, *i.e.*

$$\delta T = \frac{T}{4}\alpha\frac{\delta P_{\text{abs}}}{P_{\text{abs}}}$$

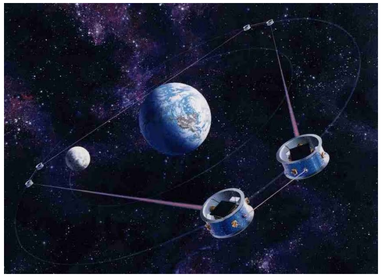
Absorptivity of the filter



OMEGA Sun Filter

Path Noise

For fluctuations in insolation at 1 mHz, $\frac{\delta P_{\text{abs}}}{P_{\text{abs}}} = 0.001\,\text{Hz}^{-1/2}$

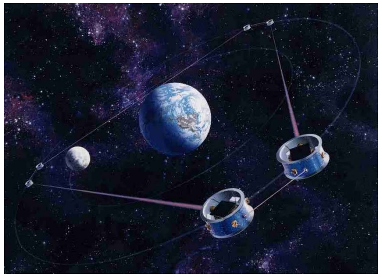


OMEGA Sun Filter
Path Noise

For fluctuations in insolation at 1 mHz, $\frac{\delta P_{\text{abs}}}{P_{\text{abs}}} = 0.001\,\text{Hz}^{-1/2}$

α = 2% and the temperature of the spacecraft is 240K, so

$$\delta T = \frac{240\text{K}}{4}(0.02)(0.001\ \text{Hz}^{-1/2}) = 1.2\times10^{-3}\,\text{K/Hz}^{1/2}$$



OMEGA Sun Filter
Path Noise

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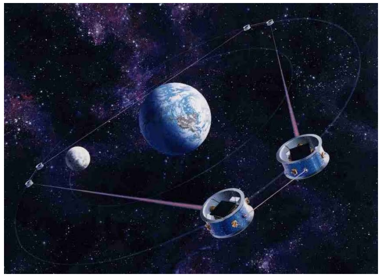
$$\delta T = \frac{240\text{K}}{4}(0.02)(0.001\ \text{Hz}^{-1/2}) = 1.2\times10^{-3}\,\text{K/Hz}^{1/2}$$

and the variation in the optical path length in 2 cm of glass is

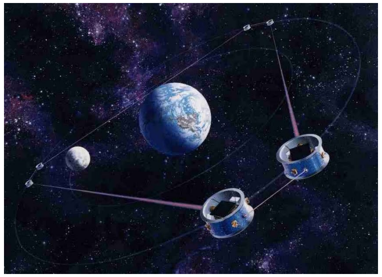
$$\delta L = (0.02\text{m})(2\times10^{-7}\,\text{K}^{-1})(1.2\times10^{-3}\,\text{K/Hz}^{1/2}) = 4.8\,\text{pm/Hz}^{1/2}$$



OMEGA Sun Filter

Path Noise

For the slow absorption of the total insolation, $\dfrac{\delta P_{\text{abs}}}{P_{\text{abs}}} = 1$

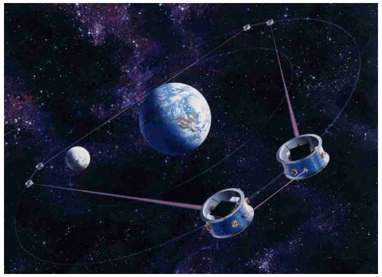


OMEGA Sun Filter
Path Noise

For the slow absorption of the total insolation, $\frac{\delta P_{\text{abs}}}{P_{\text{abs}}} = 1$

The orbital-period change in the sun filter temperature is

$$\delta T = \frac{240\text{K}}{4}(0.02)(1) = 1.2\text{K}$$



OMEGA Sun Filter

Path Noise

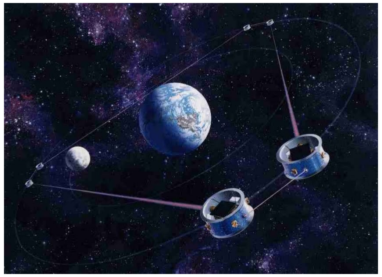
For the slow absorption of the total insolation, $\frac{\delta P_{\text{abs}}}{P_{\text{abs}}} = 1$

The orbital-period change in the sun filter temperature is

$$\delta T = \frac{240\text{K}}{4}(0.02)(1) = 1.2\text{K}$$

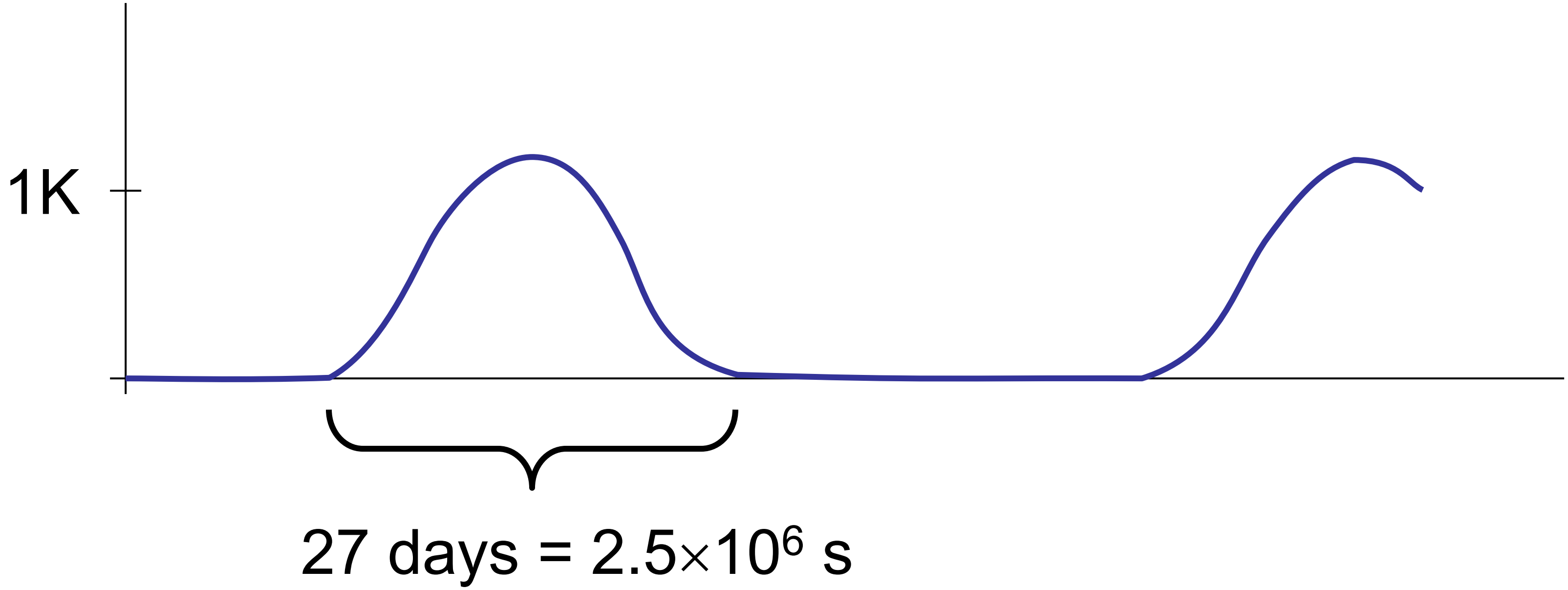
and the change in optical path length through the filter is

$$\delta L = (0.02\text{m})(2\times 10^{-7}\,\text{K}^{-1})(1.2\,\text{K}) = 4.8\,\text{nm}$$

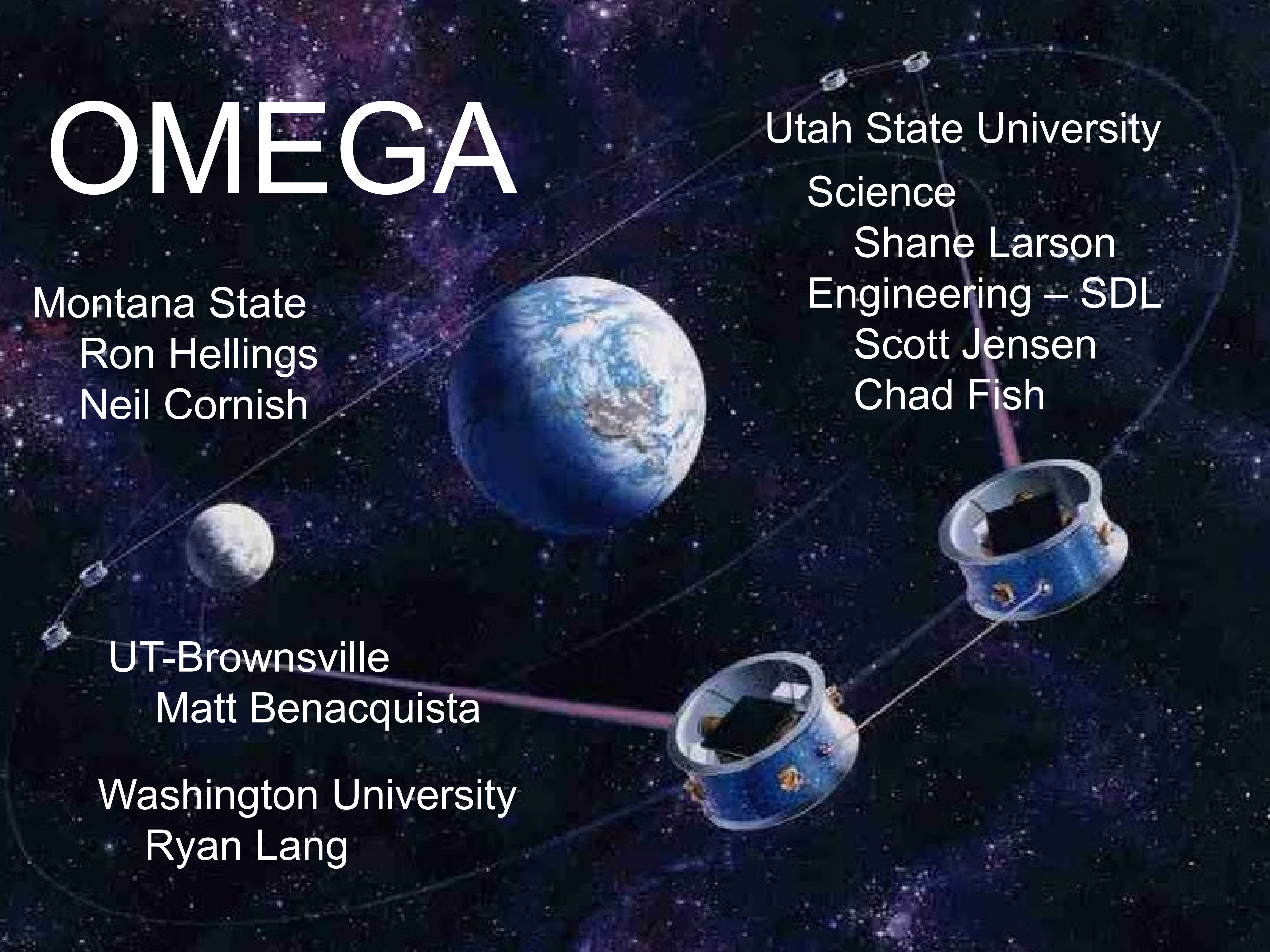


OMEGA Sun Filter

Path Noise



The ability to model and then high-pass filter this signal below 10^{-3} Hz may be tested in the laboratory.



OMEGA

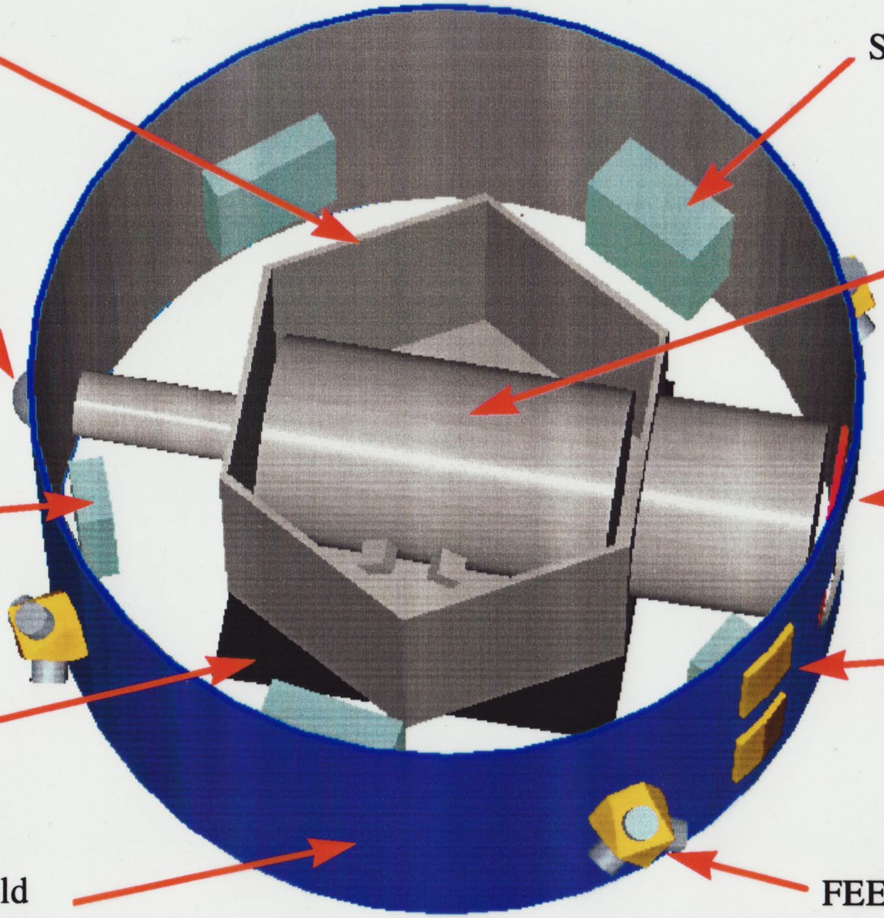
Utah State University
Science
  Shane Larson
Engineering – SDL
  Scott Jensen
  Chad Fish

Montana State
  Ron Hellings
  Neil Cornish

UT-Brownsville
  Matt Benacquista

Washington University
  Ryan Lang

OMEGA Microprobe Layout



Payload Bay

AFT Assembly

Payload
Electronics

Main Laser
Radiator

Sun Shield
(Solar Cells)

Spacecraft Electronics

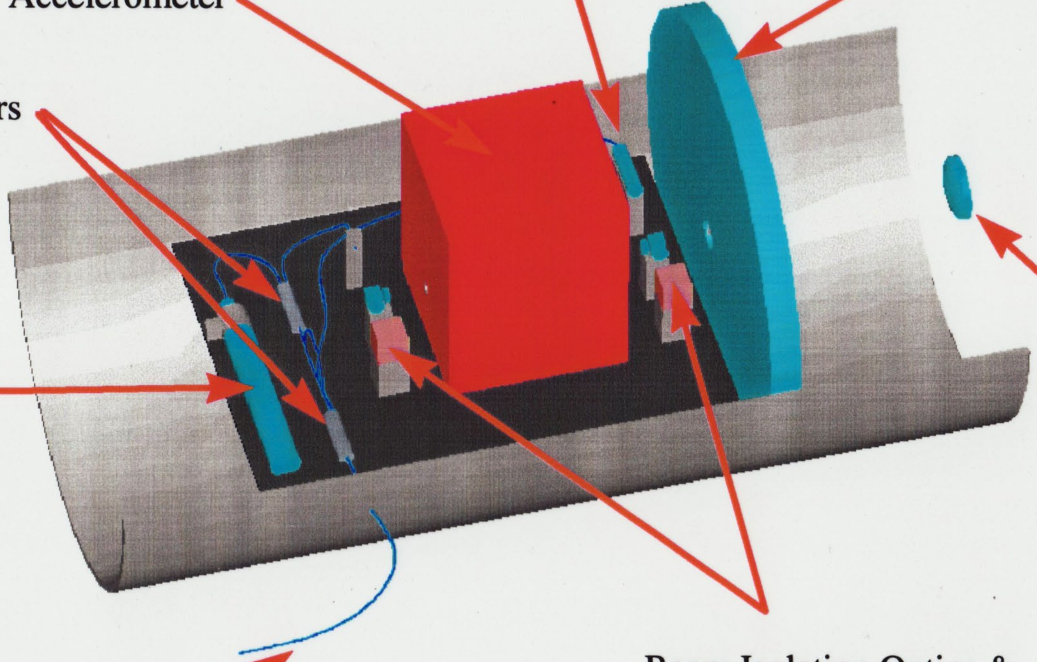
Optical Bench

Sun Filter

Telecom
Antenna

FEEP Cluster

OMEGA Optical Bench Layout



Fiber Positioner

Primary Mirror

Accelerometer

Beamsplitters

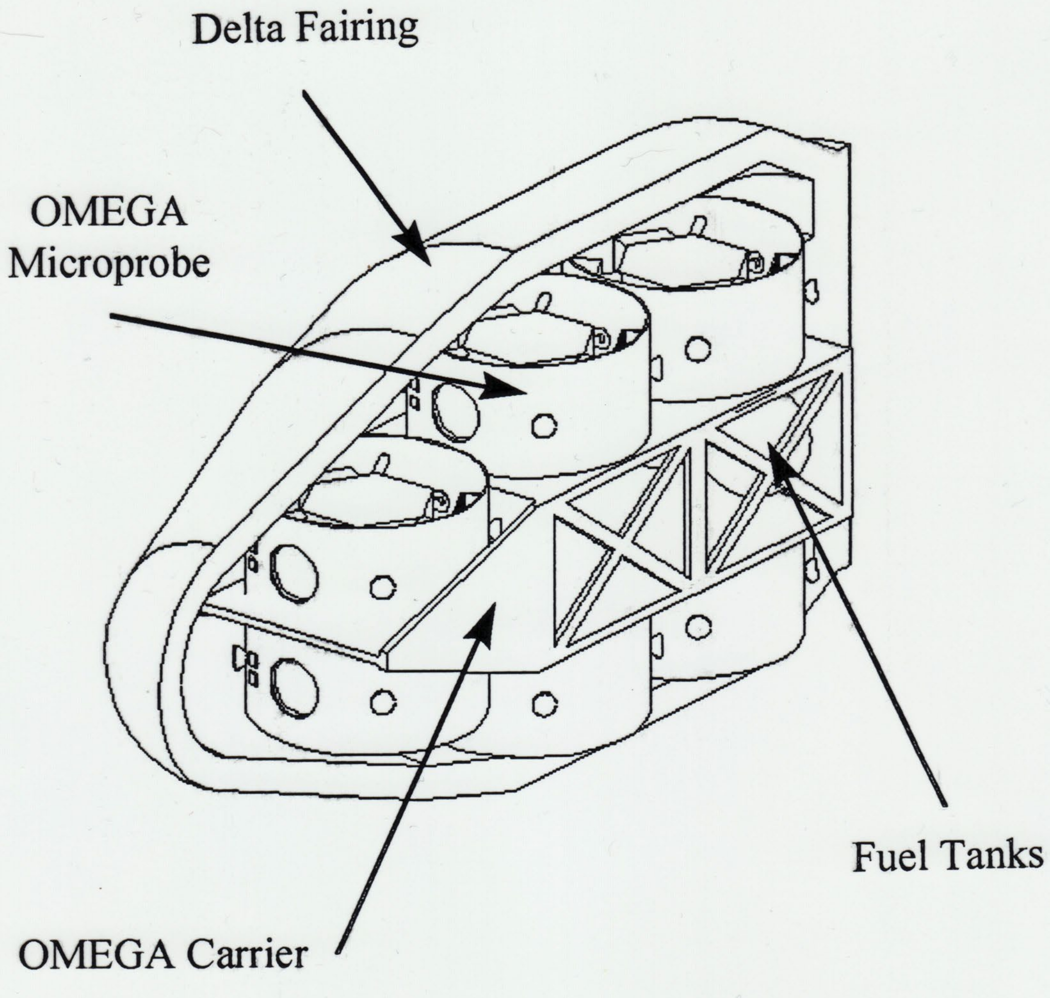
Fabry-Perot
Cavity

Secondary
Mirror

Beam Isolation Optics &
Quadrant Photodiodes

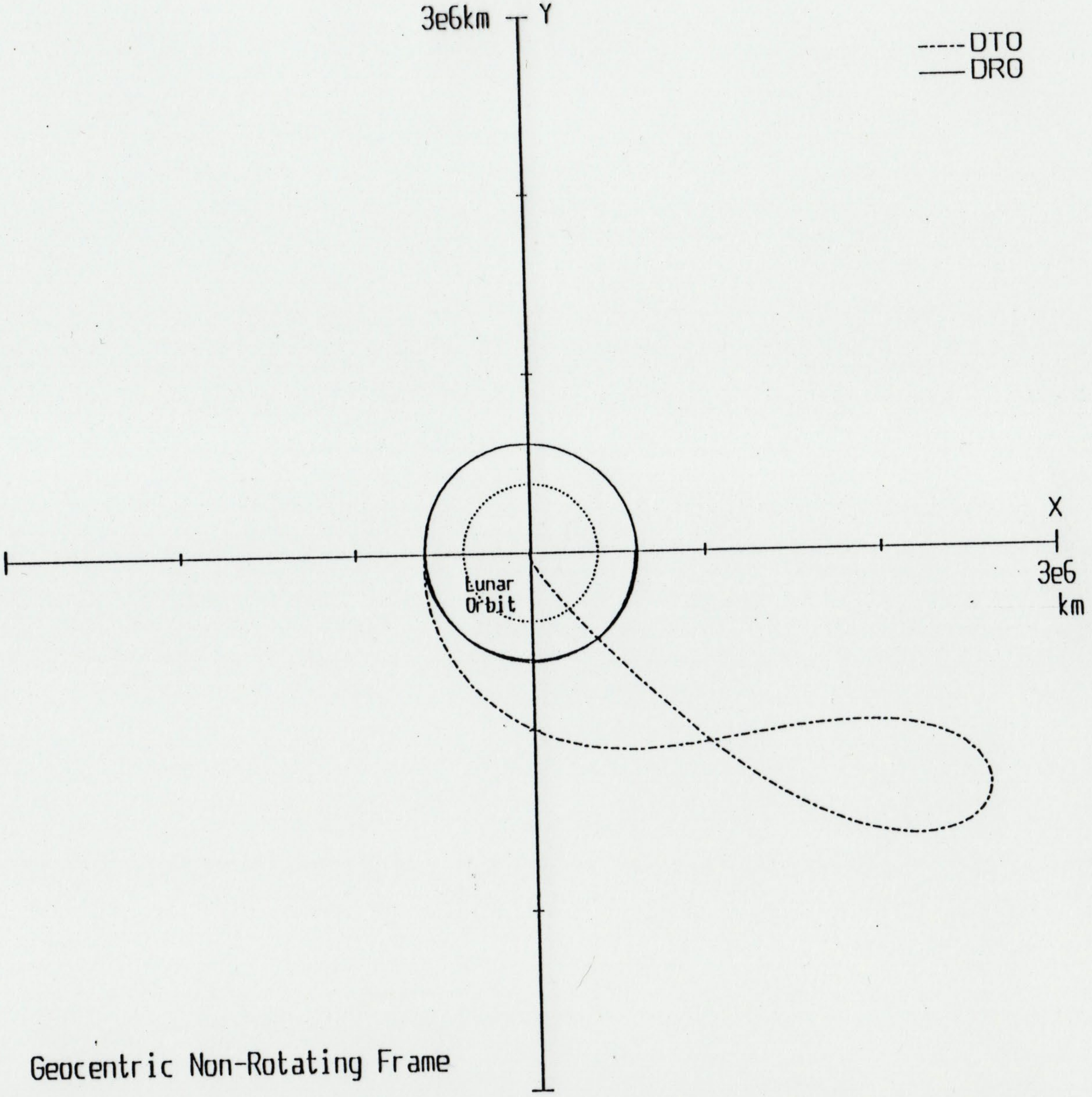
Fiber in from Laser

OMEGA Carrier
Inside the Delta Fairing



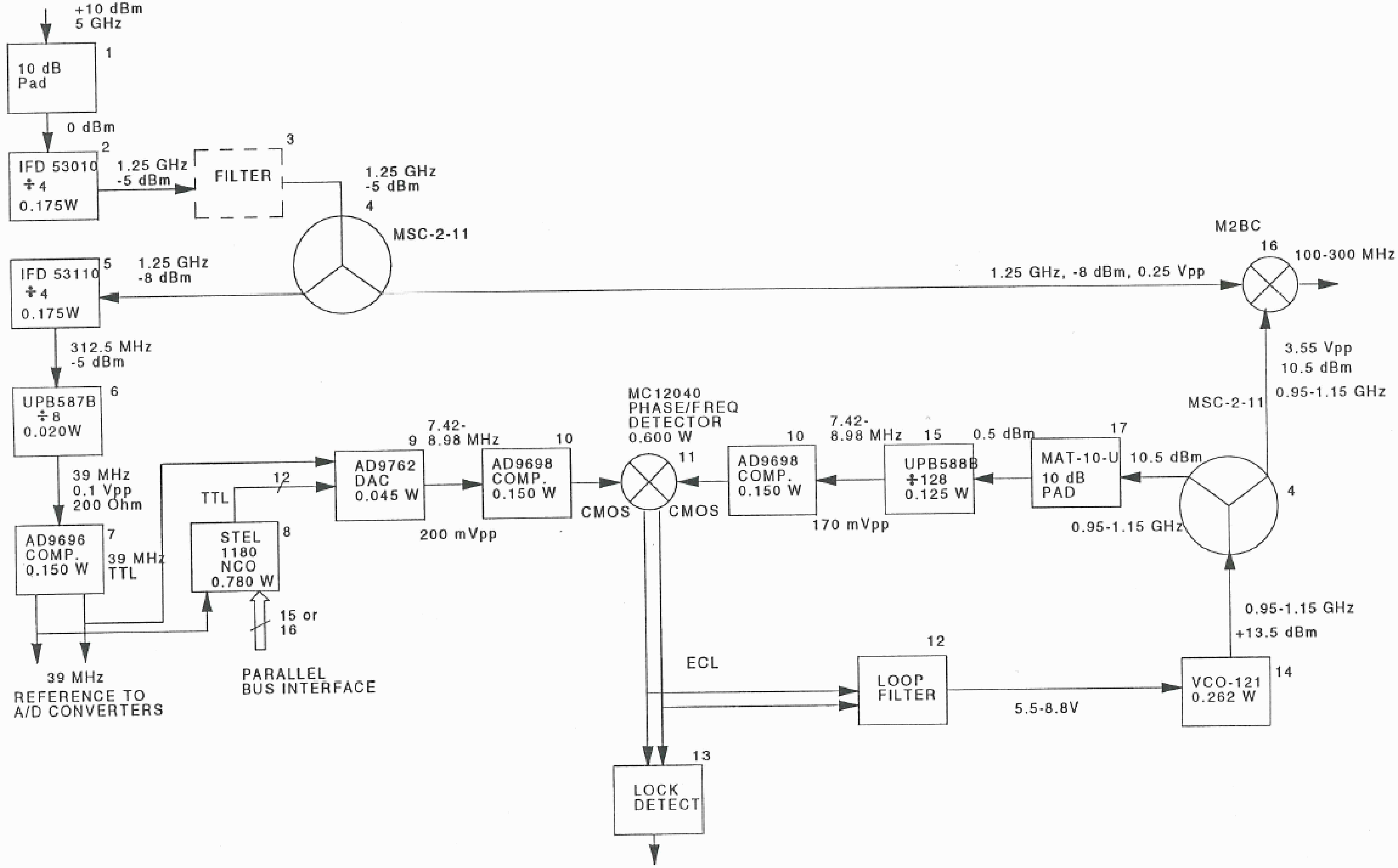
Class-B Transfer to a 600,000 km DRO

C_3=-.1 km^2/s^2 TOF=170 days ΔV_i=170 m/s

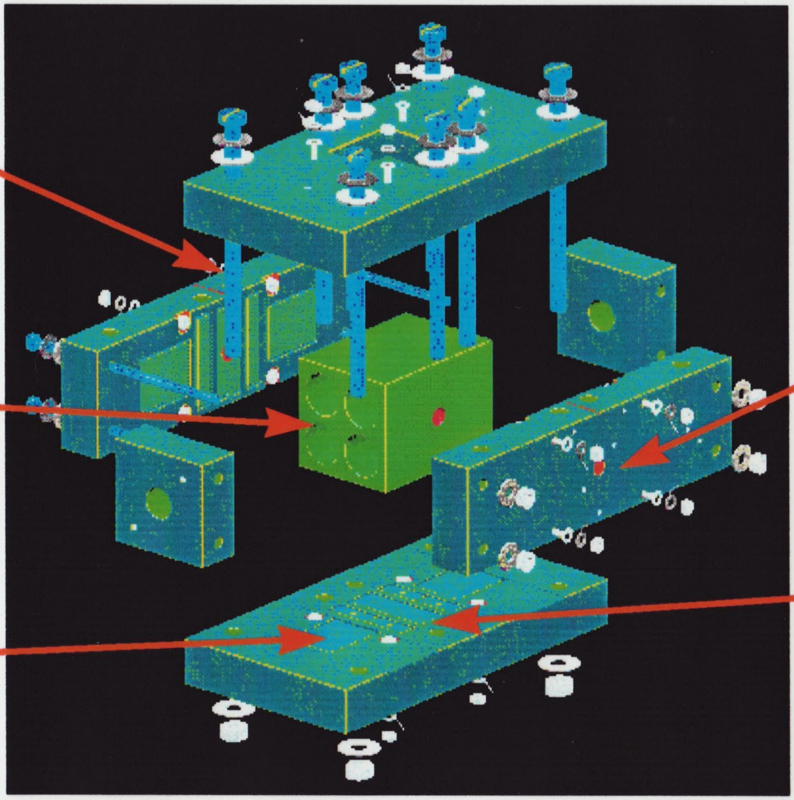


SYNTHESIZER

F. M. Cady
EE-CpE
Montana State University
8/28/97



OSCAR Exploded View



Caging Mechanism

Proof Mass

Sensitive Axis
Electrodes

UV Discharge
Beam Access

Transverse Axis
Electrodes