16.89J / ESD.352J Space Systems Engineering
Spring 2007

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Lunar Telescope Project

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Assignment 2

In this assignment you will map out the key relationships between angular resolution, signal to noise ratio and system cost for a telescope with a circular monolithic aperture at three wavelengths: radio frequency, infrared and visual. The purpose of this exercise is for you to obtain a better understanding the relationships between key aspects of the problem such as imaging performance in terms of isolation and sensitivity, system mass, system cost and location.

Out: Friday, February 16, 2007
Due: Friday, February 23, 2007

You can solve this assignment in teams of two. When uploading your answer, upload a Word or Latex file with your report and a zip file with all your calculations. You may choose whatever tool suits you best (Matlab, Excel, Mathematica …).

Nomenclature

θ	angular resolution, rad
D	circular aperture diameter, m
C_D	cost of an aperture of diameter D, $
m_D	mass of an aperture of diameter D
C_T	"total" system cost
ΔV	change in velocity, m/s
g	mean gravitational acceleration on the Earth's surface, 9.81 m/s^2
I_{sp}	specific impulse
SNR	signal to noise ratio

Parameters

λ_{RF}	$2.1\ 10^{-1}$m
λ_{IR}	$1\ 10^{-5}$m
λ_{Vis}	$5\ 10^{-7}$m

Reference Target: G2V main sequence star (sun-like), distance: 3000 parsecs

ΔV:	Earth to Low Earth Orbit (LEO):	9.5 km/s
	LEO to Earth-Sun L2:	3.3 km/s
	LEO to Earth-Moon L1:	3.8 km/s

LEO to Low Lunar Orbit: 4.0 km/s
Lunar Orbit to Lunar Surface: 1.9 km/s

Propulsive Efficiency (LOX, H2): I_{sp}=450 sec

Transportation cost from Earth's surface to LEO: $10,000/kg

Launch vehicle payload fairing diameter limit: 6 m

Cost coefficients for primary aperture (Meinel's law): $C_D=\alpha D^{\beta}$

$\beta=2.8$ (use this for all cases unless you can argue a better number)

Your mass and cost model for the telescope should include an overhead for the rest of the optics and the spacecraft/telescope structure and other subsystems, not just the primary aperture.

Table for α: Acquisition cost for a circular monolithic telescope primary aperture with an RMS wavefront accuracy of $\lambda/10$ (fill in the remaining values based on your own research)

$ FY10	Earth	In Space	Lunar Surface
RF			
IR			
Vis	500,000		

Write a report that answers the following questions (make simplifying assumptions were necessary):

1. What are the key relationships?

    a. Assemble the main equations that capture the angular resolution, signal to noise ratio, telescope mass, acquisition cost, transportation costs and observation time. List these equations in your report along with the nomenclature you have chosen to use. Cite your sources.

    b. Show the relationships between these equations in a block diagram or in an N^2 diagram (or DSM)

    c. Write about ~1-2 pages of narrative to explain your quantitative and qualitative understanding of these relationships.

2. Imaging Performance versus system cost[1]?

    a. Create the following three plots:
        i. angular resolution [deg] versus system cost [$] for a fixed SNR=10 for a radio telescope (at λ_{RF}) located at the Earth's surface, in LEO, at the ESL2 and at the lunar surface[2]
        ii. angular resolution [deg] versus system cost [$] for a fixed SNR=10 for an infrared telescope (at λ_{IR}) located at the Earth's surface, in LEO, at the ESL2 and at the lunar surface[3]
        iii. angular resolution [deg] versus system cost [$] for a fixed SNR=10 for a visual telescope (at λ_{Vis}) located at the Earth's surface, in LEO, at the ESL2 and at the lunar surface[4]

    b. In each of the three plots add at least one telescope that was analyzed in assignment 1 and discuss its position. Is the position realistic? (e.g. HST should fall near the "LEO-IR" and "LEO-Vis" lines in the respective plots).

    c. Write ~ 1-2 pages to discuss the plots, e.g. if there are any crossovers between the lines and so forth. What is the overriding conclusion from this analysis?

3. Other considerations
    a. Write ~ 1 page on other considerations that would need to be included in a more comprehensive analysis. In particular, given the exposure time *t*, to achieve an SNR of 10, and taking into account the location of the telescope, how many observations of the reference target star could be made per year for each telescope?
    b. What have you learned from this exercise?

[1] System cost should include the construction and transportation costs of the telescope, but not its operations costs, use FY2010 dollars
[2] There should be four lines on this plot, one for each location
[3] There should be four lines on this plot, one for each location
[4] There should be four lines on this plot, one for each location