Comparison to Optimal Discrete Transfers

Consider a mission sequence in circular synchronous equatorial orbit consisting of two transfers of 55 and 150° each. In addition, a time limitation of 6219 min. is imposed. The optimal distribution of integer phasing ellipses using the method of Ref. 1 is shown in Table 1.

Note that the total of 4 integer revolutions is the maximum possible, for the time limit assumed, using the discrete method. Using the continuous technique, which allows fractional revolutions for the 55-degree transfer, the distribution of Table 2 is found. Using a continuous transfer scheme has, for this example, reduced the ΔV requirement by 15.4%.

References

[1]Fallin, E. H., III, "Optimal Intersatellite Transfers for On-Orbit Servicing Missions," *Journal of Spacecraft and Rockets*, Vol. 12, Sept. 1975, pp. 565-568.

[2]Thomson, William T., *Introduction to Space Dynamics*, Wiley, New York, 1961.

Lightweight, Low-Cost EVA Range Estimation Aid

Wallace T. Fowler*
University of Texas at Austin, Austin, Texas
and
David B. Higgins†
SAMCO, Los Angeles, Calif.

ONCE the space shuttle becomes operational, extravehicular activities (EVA) by astronauts not physically attached to the shuttle will become commonplace. The EVA astronauts will use manned maneuvering unit (MMU) for propulsion, and can be expected to range at least as far as 500 m from the shuttle on early missions. The MMU will most likely be equipped with a lightweight radar unit for use as the primary means of range and range rate determination. The possibility exists to provide the astronaut with a backup range finder at extremely low cost. The Note discusses such a backup range finder.

At first glance, it seems that since the astronaut "knows" the size of the shuttle, he should be able to estimate the range between himself and the shuttle with no equipment at all should his radar fail. Researchers in the psychophysics of vision, such as Galanter and Galanter,[1] seem to feel that with training, a person can estimate range and range rate with reasonable accuracy. However, most of the research in this area has been limited to familiar targets in a visual field abundant with nearby referents. Very little has been done in a visual field consisting solely of a familiar object at close range.

Since we are unsure of the range estimation abilities of an astronaut in the space environment, and since the consequences of an erroneous range estimate could be serious, an MMU manual rangefinder has been devised. This rangefinder is simple, lightweight, cheap, and has no moving parts. It is designed to give the astronaut a rapid rough estimate of his distance from the shuttle (a similar rangefinder could be developed for any object of known size and shape).

Received April 23, 1976.

Index categories: Extra-Vehicular Activity; Data Sensing and Presentation or Transmission System.

*Associate Professor, Department of Aerospace Engineering and Engineering Mechanics. Member AIAA.

†2nd Lieutenant, USAF. Member AIAA.

The rangefinder is based on the well-known principle that the angle subtended by an object of known size is a function of its orientation and its distance from the observer. A brief review of the physical principle will now be given. Let d be some known readily observable physical dimension of the object to which range is being measured. For example, d might be the length, span, height, fuselage thickness, or vertical stabilizer leading-edge length of the shuttle. Although the astronaut might have scales for each of these, for the presentation here we will consider only one such observable physical dimension. Let us, for example, choose the span of the shuttle as the physical dimension upon which our range measurement might be based.

Thus, for the example $d=S_s$, where S_s is the span of the shuttle. For simplicity, let us first assume that the astronaut is directly behind the shuttle, (in the shuttle fixed yz plane). The shuttle is assumed to be oriented so that it is flying like an airplane down the flight path (wings level, upright, nose forward).

The device works in the following manner: The astronaut "holds" a graduated scale at arms length perpendicular to the line of sight between his eye (one eye closed) and the shuttle. The scale is held so that its graduated length lies in a plane parallel to the lateral axis of the shuttle. The edge of the scale is held so that the astronaut can read the number of scale graduations subtending the same angle which is subtended by the span of the shuttle. He reads the number of graduations and then looks to a distance scale which is calibrated on shuttle span for the range to the shuttle.

At large distances $s_s \cong r\theta$. Also $\ell_s \cong a\theta$ (see Fig. 1). For any given astronaut, a is a fixed quantity, i.e., arms length. The scale could be individualized so that a given range r the shuttle subtends the same number of scale divisions, regardless of the astronaut.

From the two approximate relations, the angle θ can be eliminated to give

$$\frac{\ell_s}{L_s} = \frac{a}{r} \quad \text{or} \quad r = \frac{L_s}{\ell_s}\,a$$

In order to place this information in a format easily usable by the astronaut, a scale such as that shown in Fig. 2 is provided. If, for example, the span of the shuttle subtends ten graduations, as shown, then the astronaut is about 190 to 200 m from the shuttle.

Several scales such as that shown in Fig. 2 (for length, span, fin height, etc.) would suffice if we could insure that the astronaut would always be in a position to view the shuttle so that the dimension being used as a reference is perpendicular to the line of sight. This is obviously not the case. Thus, we must provide the astronaut with some method of correcting for the visual foreshortening of the reference length when

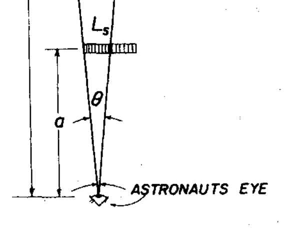

Fig. 1 Range finder geometry.

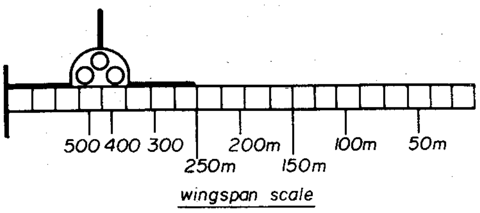

Fig. 2 Sample distance scale.

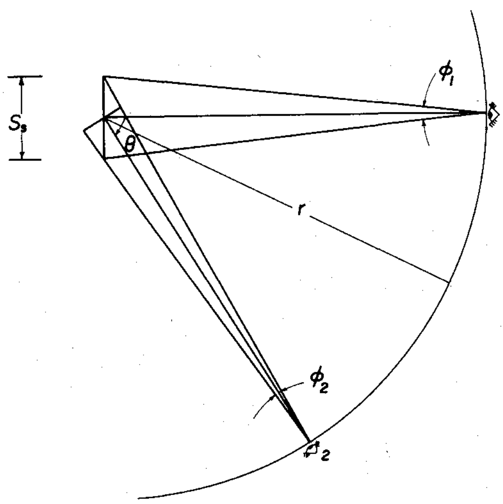

Fig. 3 Geometry of forshortening.

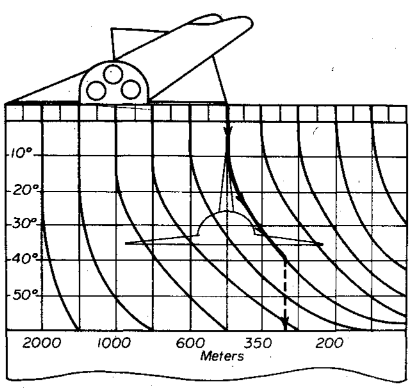

Fig. 4 Example shuttle operations range finder.

viewed from some position not in the perpendicular bisecting plane.

The geometry of foreshortening is shown in Fig. 3. In th figure, only the angles ϕ_1 and ϕ_2 have been assumed to be small. The relations between S_s and the subtended angles at position 1 and 2 are given by $\phi_1 = S_s/r$ and $\phi_2 = S_s cos\theta/r$. At position 2, the astronaut holds the scale perpendicular to the line of sight and reads an indicated range r^i. This range is obviously too large and a correction factor needs to be introduced. The relation between the indicated range and the actual range is $r = r^i \cos\theta$. Thus, for any given scale reading, δ^i, the corrected scale reading corresponding to any angle, θ, between the line of sight and a normal to the reference dimension is given by $\delta = \delta^i \cos\theta$. If the values of $\delta(\theta)$ over a range of values of θ are plotted using the range scale for $\theta = 0$ as a basis, a scale such as that shown in Fig. 4 can be plotted.

The astronaut estimates the angle θ, holds out the scale, and reads the number of scale divisions δ^i across the top of the scale subtended by the shuttle span with the scale held perpendicular to the line of sight. He then moves along a curved δ line down from the scale to the estimated value of θ (this gives δ). Then he reads directly down to the bottom of the scale to read range. The case for $\delta^i = 12$ divisions and $\theta = 40°$ is shown on the figure. The indicated range between the astonaut and the shuttle is about 265 m.

Since loose objects in an uncontained weightless environment are undesirable, it is assumed that the range finder described above would be tethered to the astronaut. It would be advantageous to make the tether some standard length so that when held taut the eye-to-card distance would be the same for all astronauts. If this were done, the scales would not need to be individualized. A good attaching point for the tether might be the helmet collar ring. The manual range finder proposed could easily be tested in a visual simulator, and could be fabricated at almost no cost. It is reliable and probably accurate enough to use as a backup unit.

Reference

[1]Galanter, E. and Galanter, P., "Range Estimates of Distant Visual Stimuli," *Perception and Psychophysics*, Vol. 14, 1973, pp. 301-306.

Shapes of Blunt-Nosed Missiles of Minimum Ballistic Factor

V.B. Tawakley* and S.C. Jain†
Defence Science Laboratory, Delhi, India

Introduction

RECENTLY, several papers have been published by various authors, e.g., Berman,[1] Miele and Huang,[2] Heidmann,[3] and Tawakley and Jain[4-6] for determining shapes of bodies of minimum ballistic factor. Jain and Tawakley[7] developed a variational solution, described briefly later on, for extremizing the sum of the products of the powers of several integrals. They then applied this solution to find the class of sharp-nosed slender axisymmetric missiles of minimum ballistic factor in hypersonic flow, under the assumptions that the pressure coefficient obeys Newtonian law and the surface averaged skin-friction coefficient is constant. However, sharp-nosed bodies experience severe aerodynamic heating during re-entry, and therefore the practical vehicle for hypersonic flight will of necessity have a blunt nose. The problem of finding a blunt-nosed missile of minimum ballistic factor is therefore investigated here. It has been shown that in the case where the wetted area and diameter of the body are known a priori, and the length is free, the variational scheme described is directly applicable and an analytical solution can be obtained easily.

Extremization of the Sum of the Powers of Several Integrals

For the extremization of a functional expression of the type

$$I = \prod_{j=1}^{n} (I_j)^{\alpha_j} + k \prod_{j=1}^{n} (I_j)^{\beta_j}$$

k being a known constant while the exponents α_j, β_j are known positive and negative quantities, and I_j denotes positive integrals of the form

$$I_j = \int_{x_i}^{x_f} f_j (x,y,y')\, dx \qquad j = 1,2,\ldots,n$$

Received Nov. 4, 1975; revision received May 5, 1976. The authors are grateful to B.K. Banerjea, Director, Defence Science Laboratory, Delhi, for permission to publish this work.

Index category: LV/M Configurational Design.

*Principal Scientific Officer, Systems Engineering Division.

† Junior Scientific Officer, Systems Engineering Division.