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Aircraft Landing Approach Paths With the Rainbow Optical Landing System

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ABSTRACT

The Rainbow Optical Landing System is designed to present color-sequence-encoded sink-rate-error information to a pilot landing aboard a carrier. As the name implies, the Rainbow system utilizes a tricolor, dynamic light beam projected into the sky from a point near the landing spot.

The approach path and associated sink rate of an aircraft whose pilot is flying the Rainbow system have been determined and plotted for several values of different system parameters. On the basis of these plots, optimal values of beam-pattern parameters can be selected. In addition, the effects on overall system performance of aircraft approach parameters such as initial error, initial range, and rate of approach to the carrier, can be displayed in the form of graphs and numerical tables.

This analytical methodology can be readily applied to other systems which display higher-derivative-command signals.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

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AIRCRAFT LANDING APPROACH PATHS WITH THE RAINBOW OPTICAL LANDING SYSTEM

INTRODUCTION

Background

The Rainbow Optical Landing System was designed to facilitate the safe landing of high-performance aircraft aboard carriers. The system provides the pilot with precise glide-path control information. As the name implies, the Rainbow uses projected beams of colored light as encoded guidance information for display to the pilot.

From a unit located near the landing point, range-independent, high-gain, sink-rate commands are presented to the pilot in the form of a sequential display of three colors – red, white, and blue.* The pilot interprets a sequence of red-white-blue as the command to increase his sink rate. The reverse blue-white-red sequence is the command to decrease sink rate. A steady red, white, or blue indicates that sink rate is appropriate to acquire and maintain glide path. "On glide path" is indicated by a steady green. Flashing green and flashing red signify that the aircraft is at the vertical extremes of the projected pattern – either high or low. The sequence command for sink-rate correction is consistent regardless of whether the aircraft is above or below glide path. A decelerating sequence rate indicates a sink-rate correction of the proper sign but insufficient amount. Sequence acceleration indicates increasing sink-rate error. Sequence reversal indicates overcorrection.

The sink-rate commands as observed by the pilot are generated by means of the interaction of his aircraft sink rate with the vertical rate of the moving, projected beams of light. In order that the command be always appropriate to guide the aircraft asymptotically to glide path, the beam movement is exponential in nature.

The dynamic, projected array of colored lights is developed by a modified slide projector in which the conventional slide has been replaced by a patterned, transparent drum which rotates about the light source in the focal plane of the objective lens (Fig. 1). The programming of the dynamic beam of light determines the flight path of an aircraft which the pilot is controlling so as to follow the commands of the Rainbow system. The characteristics of such a flight path can be varied by manipulation of the design parameters of the color transparency on the Rainbow drum (1).

Rainbow Beam Pattern and Aircraft Flight Path

Early development and initial testing of the system included efforts to obtain the optimum dynamic characteristics of the projected Rainbow beam pattern. The optimum projected pattern was defined in terms of the "programmed flight path," which is the path an aircraft would follow with respect to the carrier if the pilot were to maintain a zero sink-rate error at all times, after he began to fly the Rainbow. Such a path is determined by the dynamic characteristics of the projected beam and the location of the aircraft when the pilot begins to fly the system.

*One possible alternative means of encoding such information, i.e., a "two-color system," is discussed in Appendix A.

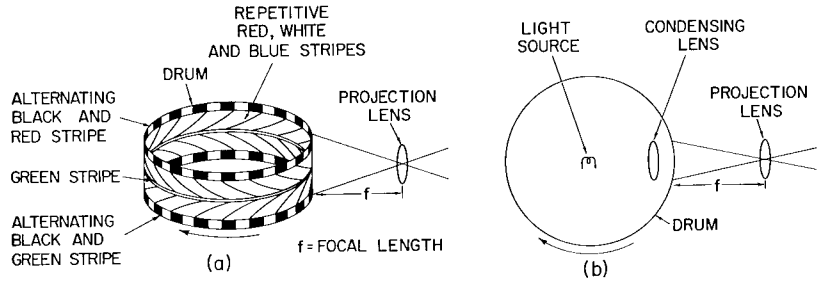

Fig. 1 - Schematic representation of rotating drum and lens system: (a) side view, (b) top view

The optimum programmed flight path is asymptotic to the glide path; the vertical rates experienced by an aircraft flying this path are not excessive for aircraft structural limitations; the time (or distance) until acquisition of the glide path is minimized. A mathematical study was performed to determine the effects on the programmed flight path of various parameters of the projected pattern.

Both linear and exponential beam patterns were considered. The linear pattern, however, resulted in a programmed flight path which was not asymptotic and which had an acceptable glide-path intercept time only when the vertical rates became excessive. This type pattern was discarded.

The exponential pattern produced a programmed flight path asymptotic to the glide path. The vertical rates and the glide-path intercept time with this type of projected pattern depend on the value of the exponential time constant. For instance, the shorter the time constant, the shorter the time to intercept glide path, but the greater the vertical rates. However, the longer the time constant, the more system damping and the greater the ease of acquiring and maintaining glide path. There is, then, some trade-off in the selection of the proper time constant as based on vertical rates and intercept time and system damping as well.

There is one other determining factor in the selection of the time constant. This factor, known as the "potential reversal," refers to the possibility of the color sequence reversing direction due to overcorrection of a sink-rate error. Clearly if the beam rate exceeds the maximum acceptable vertical rates for the aircraft, the pilot will never observe a color reversal if he adheres to the rate restrictions on his craft. In order to realize the full potential of the Rainbow system, it is necessary to design for the potential reversal and at the same time to maintain sufficient beam rate to produce an acceptable glide-path intercept time.

It is for the design of the optimum projected pattern on the basis of the above criteria that this study was intended. A serendipitous aspect, however, was the determination of the effect of airspeed on the programmed flight path. Since various classes of aircraft have different landing speeds, and since landing speed for a given aircraft is a function of gross weight, the effects of airspeed on the programmed flight path influence the feasibility of several craft using the system simultaneously or the criticality of airspeed in the design of the projected pattern.

Of interest also is a table of the aircraft vertical rates experienced as the pilot flies the Rainbow (having the chosen projected pattern) from various angular errors at various ranges.

PROGRAMMED FLIGHT-PATH EQUATIONS

Consideration of the geometrical properties of the entire system – i.e., Rainbow unit, projected pattern, and aircraft in the beam – permits expression of the programmed flight path as a function of the design parameters of the beam pattern, the initial position of the aircraft in the beam, and the range rate of the aircraft. Optimization of the programmed flight path for various initial positions of the aircraft leads to selection of the best values for the drum-pattern design parameters. Further, the effects of airspeed on the programmed flight path can be illustrated by using two values of range rate. In this study, range rate is assumed constant for any given approach and also is assumed to differ from airspeed only by a constant. This approximation is a reasonable one, since standard operating procedure calls for an attempt to be made to maintain a fixed wind speed along the deck and also because of the small angles involved.

In Fig. 2, the configuration to the right of the lens, which is considered as the origin, represents the projected beam pattern through which the aircraft flies. The aircraft is located at some altitude h and at some range R from the desired point of touchdown. Its angular position in the beam is represented by $\beta_a(t)$; β_c denotes commanded (glide path) angle and $\beta_e(t)$ the angular error of the aircraft from the glide path. It should be noted that, due to the way in which the angles are defined, $\beta_e(t)<0$ when the aircraft is <u>above</u> the glide path. This sign convention is consistent with general block-diagram terminology, which defines error as the difference between input and output, or as commanded angle minus actual angle; i.e., $\beta_e(t) \equiv [\beta_c - \beta_a(t)]$.

From Fig. 2, a general equation $h = h(t)$ describing the position of the aircraft as a function of time can be developed. For small angles,

$$h = R\,\beta_a(t)$$

or

$$h = R\,[\beta_c - \beta_e(t)]. \tag{1}$$

The configuration to the left of the origin is a schematic representation of the rotating drum with the pattern on it. Since the projected image must be focused at optical infinity (2), the distance between the lens and the drum must be equal to the focal length F of the lens. (Because the drum is to the left of the origin, F is assumed to have a negative value.) The drum-lens system is tilted at an angle β_c with respect to the horizontal.

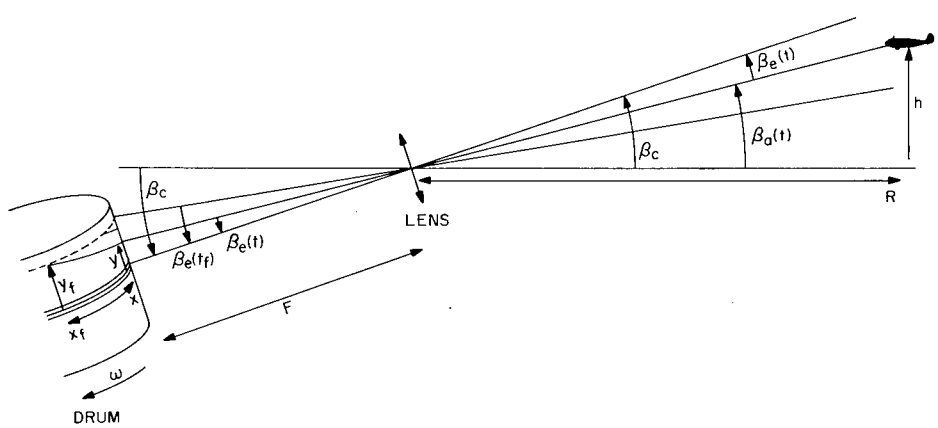

Fig. 2 - Rainbow pattern projection

The general equation $y = y(x)$ for the pattern on the drum can be written for the exponential pattern,

$$y = y_f e^{-X/L}$$

where y_f represents the outer limit of the pattern, and L is the decay constant. The horizontal distance on the drum can also be expressed as a function of time

$$X = X(t) = x - x_f = \omega \pi D(t - t_f),$$

where D is drum diameter and ω is the constant rotation speed. The quantity $t - t_f$ represents the time elapsed while the pattern moved a distance $x - x_f$. The decay constant $L = \omega \pi D \tau$, where τ is the time constant of the projected beams. (A detailed derivation of these expressions is found in Ref. 1.)

The equation $y = y(t)$ can now be written

$$y = y_f e^{-(t - t_f)/\tau}. \tag{2}$$

It was stated earlier that the programmed flight path is the path which an aircraft would travel if a pilot maintain zero sink-rate error at all times after acquisition of a rainbow color. The altitude and altitude rate of the aircraft can then be expressed in terms of the critical parameters of the beam pattern, since, after beam acquisition, aircraft and colored beam altitude will always be equal.

From Fig. 2, angular error of the aircraft $\beta_e(t)$ is seen to be related to y, the vertical displacement on the drum, by the expression

$$y = -F\, \beta_e(t). \tag{3}$$

Since

$$y_f = -F\, \beta_e(t_f),$$

then

$$y = -F\, \beta_e(t_f) e^{(t_f - t)/\tau}. \tag{4}$$

From Eqs. (1), (3), and (4), the altitude at some range R of any beam, or of an aircraft flying a given beam, is developed:

$$h = R\left[\beta_c - \beta_e(t_f) e^{(t_f - t)/\tau}\right]. \tag{5}$$

The drum rotation and pattern projection are continuous and repetitive. An aircraft can intercept and begin to fly a beam at any time after the system begins to operate and at any range and altitude within the beam pattern. The aircraft path depends on the initial position of the aircraft when it intercepts a beam and on the dynamic characteristics of the beam, but not on the size of the pattern itself; i.e., $\beta_e(t_f)$.

The irrelevant terms are eliminated from Eq. (5) as follows. If the aircraft enters the beam pattern and acquires a colored beam at time $t = t_0$, at altitude $h = h_0$, range $R = R_0$, and angular error $\beta_e(t) = \beta_e(0)$, from Eq. (1), aircraft altitude is expressed

$$h_0 = R_0\, [\beta_c - \beta_e(0)].$$

At the same time, $t = t_0$, the altitude of the acquired beam is also $h = h_0$. From Eq. (5), then,

$$h_0 = R_0 \left[\beta_c - \beta_e(t_f) e^{(t_f - t_0)/\tau} \right].$$

The expression for t_f resulting from the above two equations is

$$t_f = t_0 + \tau \ln \left[\frac{\beta_e(0)}{\beta_e(t_f)} \right].$$

Substitution of this last relationship for t_f into Eq. (5) finally yields aircraft altitude as a function of time in terms of aircraft initial conditions and beam dynamics.

$$h = R \left[\beta_c - \beta_e(0)\, e^{(t_0 - t)/\tau} \right]. \tag{6}$$

Aircraft altitude can, however, be expressed solely as function of range by means of the transformation below:

$$R = \int_{t_0}^{t} \dot{R}\, dt + R_0$$

which gives $t - t_0 = (R - R_0)/\dot{R}$, where $\dot{R}$ is assumed constant and is defined as negative.

The equation for $h = h(R)$ and also $\dot{h} = \dot{h}(R)$, obtained by differentiation, can then finally be written:

$$h = R \left[\beta_c - \beta_e(0)\, e^{(R_0 - R)/\dot{R}\tau} \right] \tag{7}$$

$$\dot{h} = \left(\frac{R}{\tau} - \dot{R} \right) \beta_e(0)\, e^{(R_0 - R)/\dot{R}\tau} + \dot{R}\, \beta_c. \tag{8}$$

The above expressions fully define the programmed flight path of an aircraft having a range rate $\dot{R}$ and flying toward a glidepath angle β_c from an initial angular error $\beta_e(0)$ at range R_0; the time constant of the projected beams is τ.

Figures 3, 4, and 5 show the programmed flight path and the associated vertical rate for several values of the parameters of Eqs. (7) and (8); Figs. 6, 7, and 8 show the effect of $\dot{R}$ on these curves.

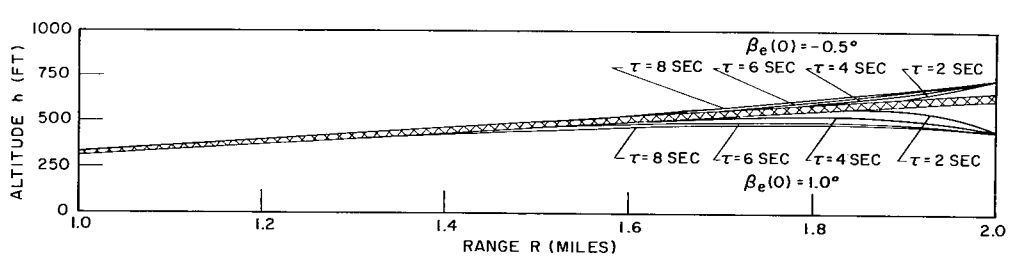

Fig. 3 - Programmed flight path $h = h(R)$. Graph has approximate 1:1 scale for realistic presentation of landing situation.
$\dot{R}$ = -120 kt R_0 = 2 mi τ = 2, 4, 6, 8 sec

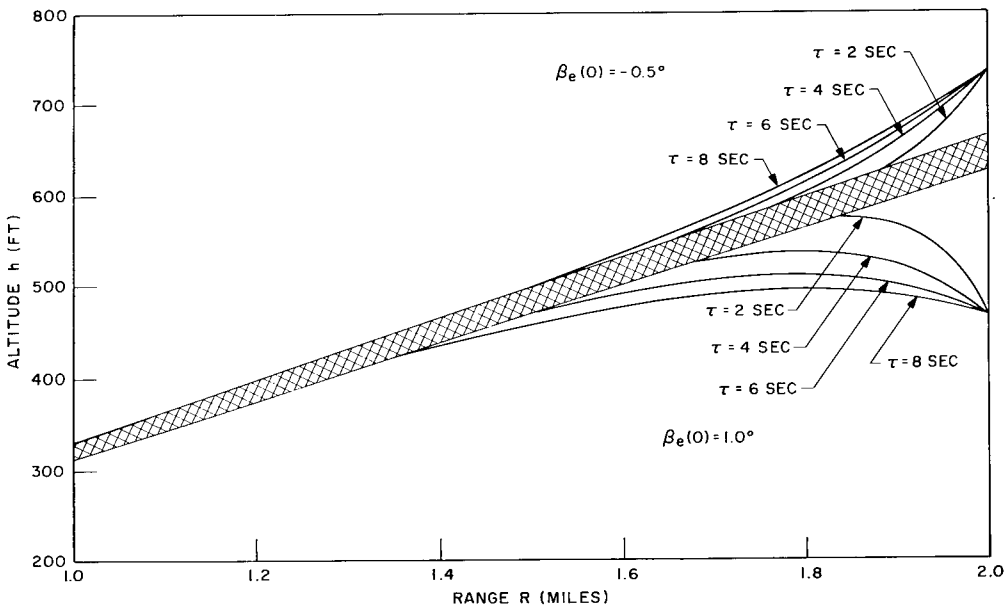

Fig. 4 - Programmed flight path $h = h(R)$. Graph has expanded vertical scale (5:1).
$\dot{R}$ = -120 kt R_0 = 2 mi τ = 2, 4, 6, 8 sec

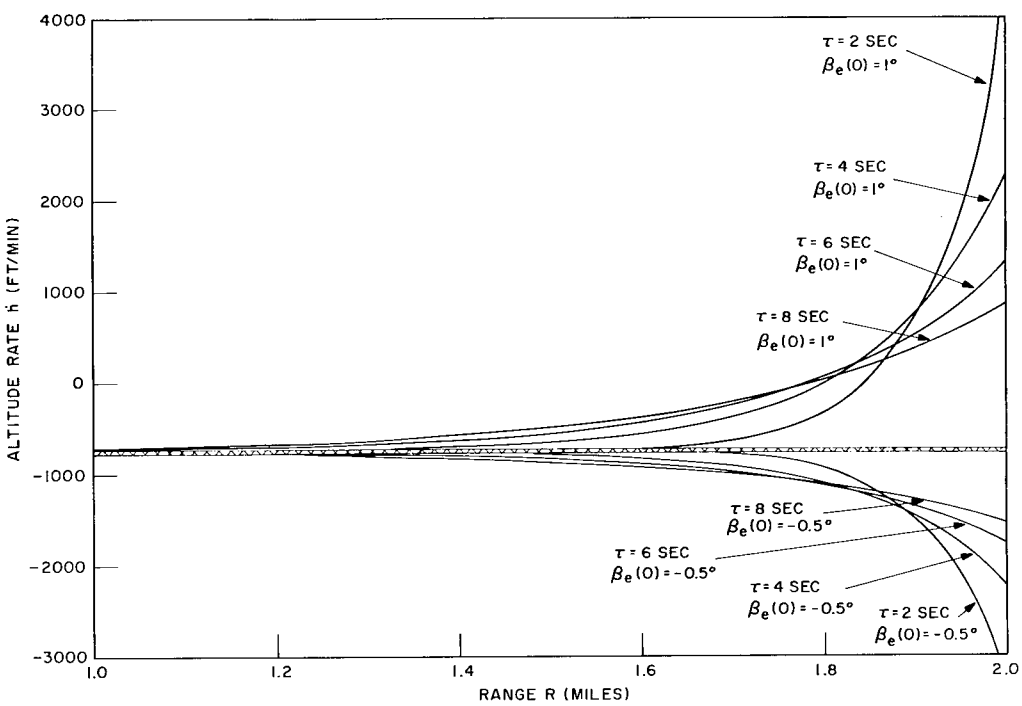

Fig. 5 - Vertical rate $\dot{h} = \dot{h}(R)$ of programmed flight path
$\dot{R}$ = -120 kt R_0 = 2 mi τ = 2, 4, 6, 8 sec

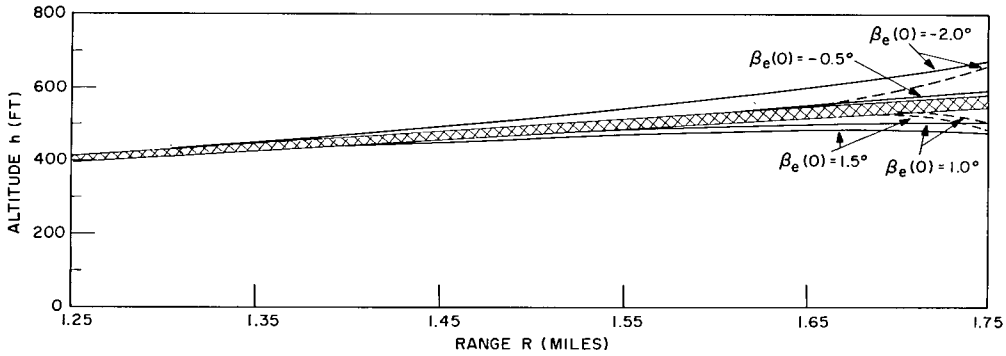

Fig. 6 - Programmed flight path $h = h(R)$. Graph has approximate 1:1 scale for realistic presentation of landing situation. $\dot{R}$ = -120 kt (solid line), -60 kt (dotted line); R_0 = 2 mi; τ = 6 sec.

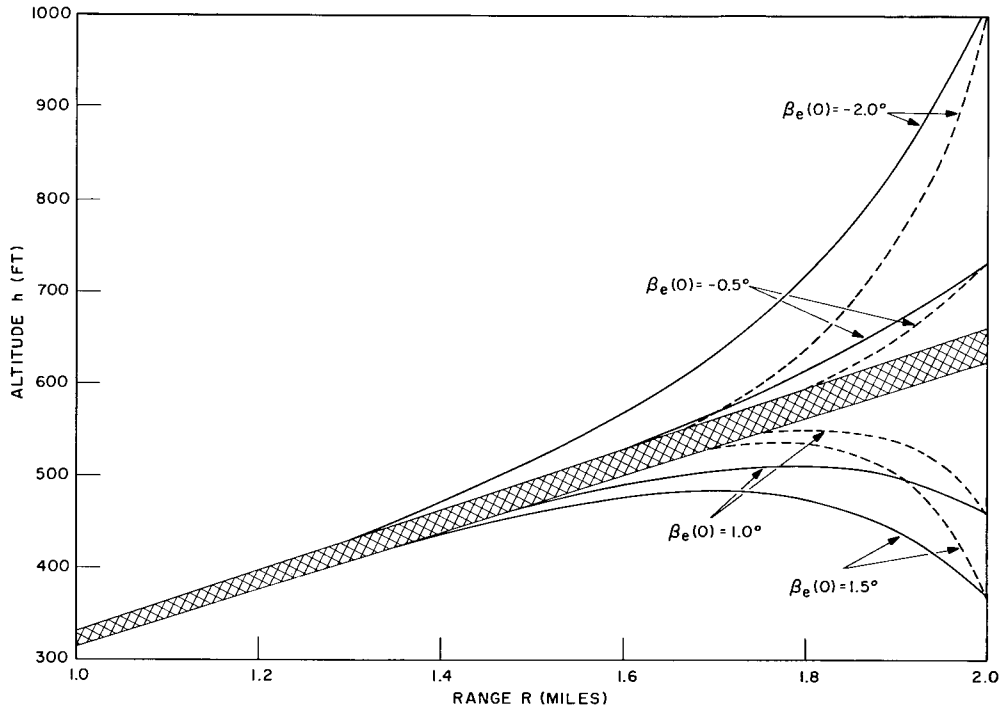

Fig. 7 - Programmed flight path $h = h(R)$. Graph has expanded vertical scale (5:1). $\dot{R}$ = -120 kt (solid line), -60 kt (dotted line); R_0 = 2 mi; τ = 6 sec.

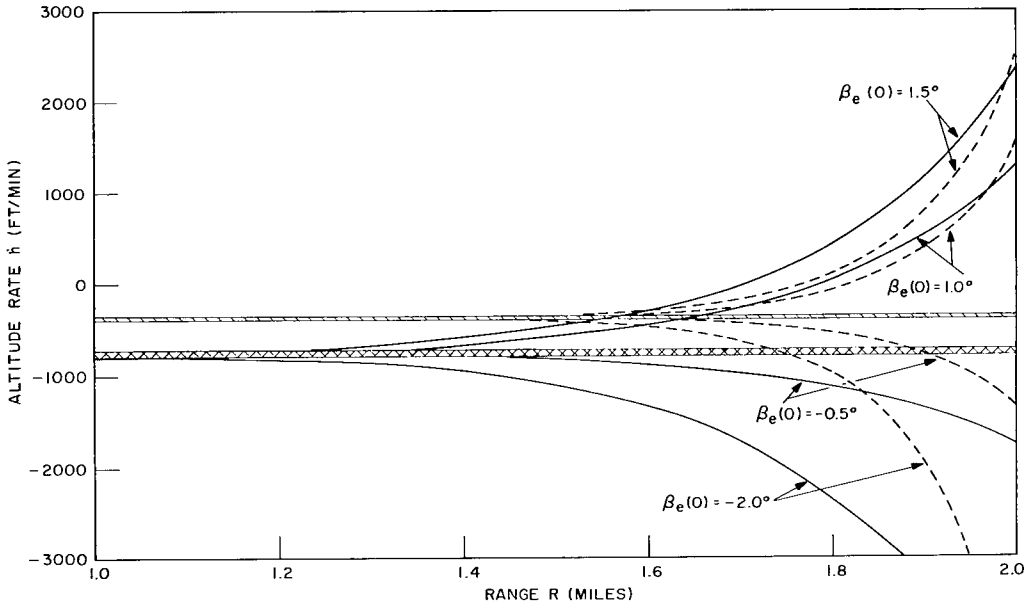

Fig. 8 - Vertical rate $\dot{h} = \dot{h}(R)$ of programmed flight path. $\dot{R}$ = -120 kt (solid line), -60 kt (dotted line); R_0 = 2 mi; τ = 6 sec

MODIFIED PROGRAMMED FLIGHT-PATH EQUATIONS

As can be seen from Figs. 3, 4, and 5, there are several choices of parameters which lead to vertical rates which the aircraft structure cannot tolerate. This condition brings up another question – whether a pilot who is initially below glide path at long range should follow a Rainbow command to climb to the glide path. While the system must be disigned to command a climb where necessary, such as at short ranges, a "modified programmed flight path" was hypothesized for the aircraft which intercepts the Rainbow beams below glide path at long range.

This modified approach calls for straight and level flight through the sequencing colors until the sequencing stops on a single color. Subsequently, the pilot maintains a zero sink-rate error, or essentially flies the standard programmed flight path. The equations for this path are in two parts.

$$h = R_0(\beta_c - \beta_e(0)) \quad \text{for} \quad R_0 \geq R \geq R_i$$
$$h = R\left[\beta_c - \beta_e(t_i)e^{(R_i - R)/\dot{R}\tau}\right] \quad \text{for} \quad R_i \geq R \geq 0 \tag{9}$$

$$\dot{h} = 0 \quad \text{for} \quad R_0 \geq R \geq R_i$$
$$\dot{h} = \left(\frac{R}{\tau} - \dot{R}\right)\beta_e(t_i)e^{(R_i - R)/\dot{R}\tau} + \dot{R}\,\beta_c \quad \text{for} \quad R_i \geq R \geq 0 \tag{10}$$

R_i and t_i represent the range and time respectively at which the aircraft in straight and level flight first zeroes the sink-rate error and then begins to fly the Rainbow beam. (The expression for R_i is derived in Appendix B.)

Figures 9, 10, 11, and 12 show the modified programmed flight path h and its derivative $\dot{h}$ as functions of range for several values of the parameters of Eqs. (9) and (10). Another

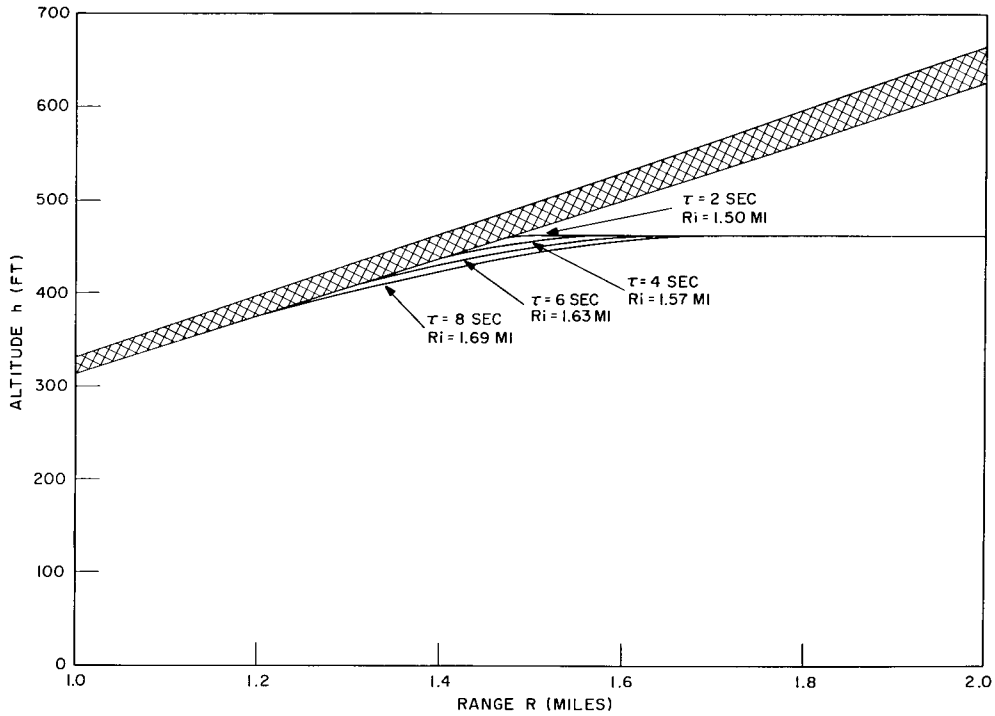

Fig. 9 - Modified programmed flight path $h = h(R)$. Graph has expanded vertical scale (5:1). $\dot{R}$ = -120 kt; R_0 = 2 mi; τ = 2, 4, 6, 8 sec; $\beta_e(0) = 1.0°$.

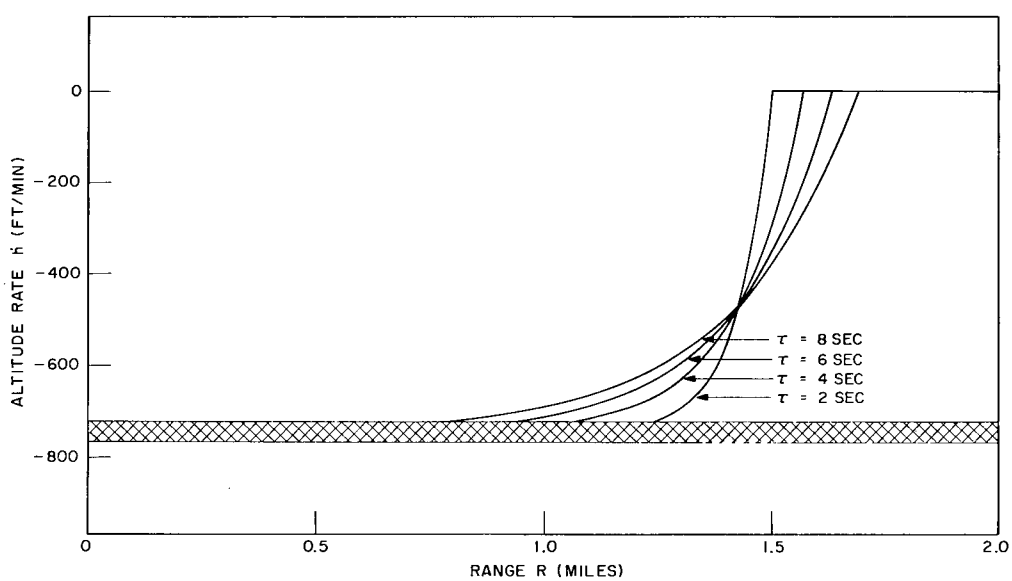

Fig. 10 - Vertical rate $\dot{h} = \dot{h}(R)$ for modified programmed flight path. Note scale change from Fig. 5. $\dot{R}$ = -120 kt; R_0 = 2 mi; τ = 2, 4, 6, 8 sec; $\beta_e(0) = 1.0°$.

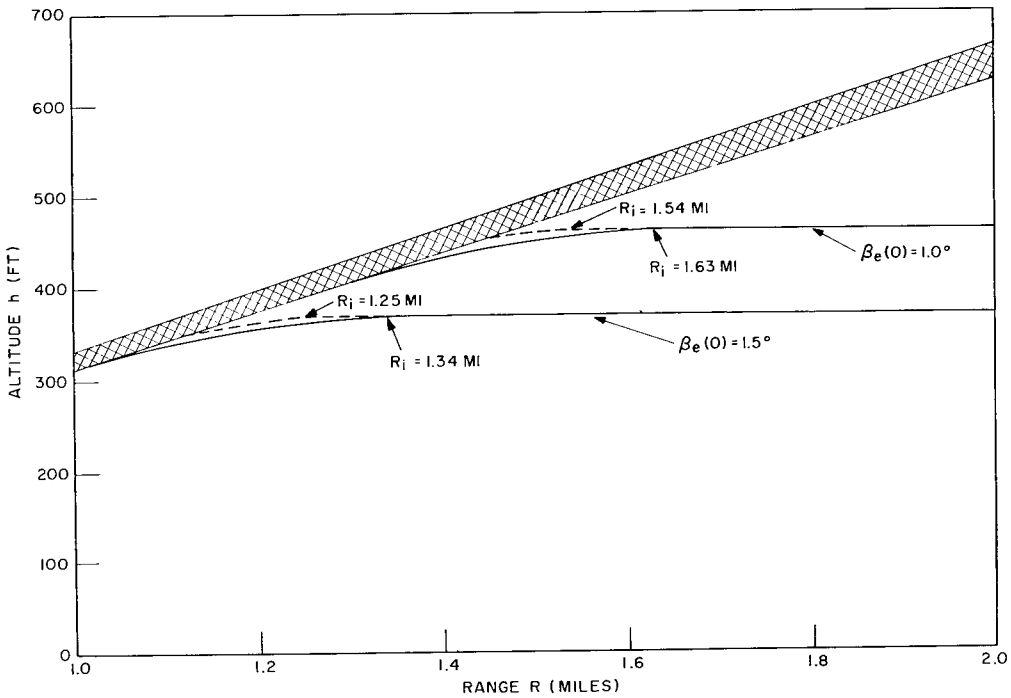

Fig. 11 - Modified programmed flight path $h = h(R)$. Graph has expanded vertical scale (5:1). $\dot{R}$ = -120 kt (solid line), -60 kt (dotted line); R_0 = 2 mi; τ = 6 sec.

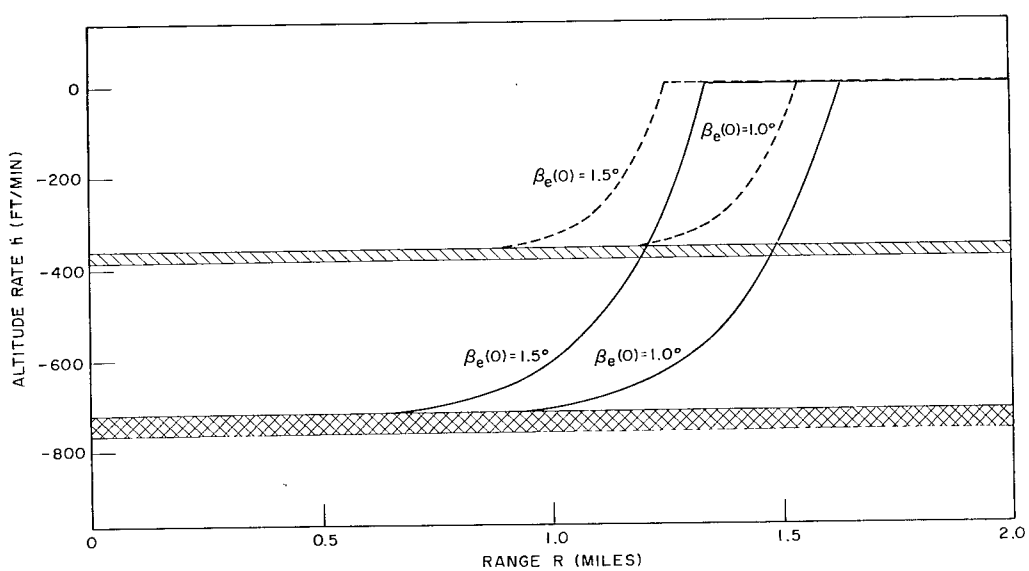

Fig. 12 - Vertical rate $\dot{h} = \dot{h}(R)$ for modified programmed flight path. Note scale change from Fig. 5. $\dot{R}$ = -120 kt (solid line), -60 kt (dotted line); R_0 = 2 mi; τ = 6 sec.

criterion of acceptability of a given τ in addition to glide-path intercept time, then, is beam-intercept time t_i, for it is desirable that the aircraft flying the modified path intercept a beam soon enough for the pilot to trim the craft and get the asymptotic path established.

DISCUSSION

Figure 3 shows the programmed flight path $h = h(R)$ of an aircraft flying each of four different projected beam patterns. A glide path ±0.1 degree wide, set at an angle of 3.5 degrees, is indicated by the cross-hatched area. The aircraft's rate of approach to the carrier is 120 knots. The initial range at which the pilot begins to fly the system is two miles. Initial errors of 0.5 degree high and 1.0 degree low are considered. The time constant τ of the projected beams is shown for values of 2, 4, 6, and 8 sec. This graph is plotted on a 1:1 scale in order to present a realistic picture of the landing approach.

Figure 4 presents the same information, but on an expanded vertical (5:1) scale for more accurate interpretation. It is evident that the programmed flight paths do not differ by great amounts for various values of τ. The glide-path intercept range R_G is between 1.3 and 1.9 mi for all values of τ. Range R_G decreases as the time constant increases; i.e., the longer the time constant, the longer time before the aircraft enters the glide-path band.

Figure 5 is a plot of $\dot{h} = \dot{h}(R)$ for the same set of conditions illustrated in Figs. 3 and 4. The cross-hatched area defines glide-path sink rates. This graph clearly indicates that a short intercept time (large R_G) is achieved only at the cost of increased vertical rates. For instance, this graph shows that to correct an error of only 0.5 degree above glide path at two miles from touchdown, the pilot flying the τ = 2 sec pattern would be commanded to subject his craft to vertical rates in excess of 3000 ft/min. Of course the vertical rates become more tolerable as the time constant is increased. At the other extreme are the rates commanded by the τ = 8 sec pattern, which are seen to be less than 1000 ft/min for the initial errors shown.

Final selection of the optimum time constant involves trade-off between minimizing vertical rates and maximizing glide-path intercept range. The τ = 8 sec pattern was rejected because of the slow approach to glide path and the fine detail required in the drum pattern. The τ = 6 sec pattern was selected as the best overall compromise. This beam pattern produced a programmed flight path characterized by an intercept range of about 1.65 mi after an initial error of 0.5 degree high, with rates never exceeding 1800 ft/min, and an intercept range of about 1.5 mi from an initial error of 1.0 degree low, with the climb rates never exceeding 1300 ft/min.

Figures 6, 7, and 8 illustrate the effects of airspeed on both the programmed flight path and the vertical rates experienced by the aircraft. Again, the glide path is set at 3.5 degrees; the initial range is two miles; the initial errors considered are 0.5 and 2.0 degrees high and 1.0 and 1.5 degrees low. Two values for the rate of approach to the carrier are considered: 120 knots represented by the solid lines, and 60 knots represented by the dotted lines. The τ = 6 sec pattern is used for all these curves. Figure 7 plots the same information as Fig. 6, but on a 5:1 scale.

From Fig. 7 it can be seen that for an initial range of two miles and an initial error of 1.0 degree low, the glide-path intercept ranges will be 1.46 and 1.74 mi respectively as a result of halving the approach rate of the aircraft to the carrier.

Figure 8 represents the vertical rates experienced by the aircraft flying the paths shown in Figs. 6 and 7. This graph shows that sink rates for the 3.5-degree glide path are different for the different values of $\dot{R}$. Glide-path sink rates corresponding to $\dot{R}$ = -60 knots are defined by the single cross-hatched area, and those corresponding to $\dot{R}$ = -120 knots by the double cross-hatched area. It is seen that the vertical rates experienced in flying the pattern are slightly greater for the slower approach speed.

On the basis of these curves, where approach rate is varied between 60 and 120 knots, it was decided that approach-rate variations of the order of 5 to 10 knots would initiate negligible variations in the programmed flight path and associated vertical rates. As a result, one projected pattern is appropriate to guide aircraft of various classes with various landing speeds to the glide path.

Figures 9 and 10, showing the programmed flight paths and associated rates for the aircraft flying the modified approach, correspond to Figs. 3, 4, and 5 with respect to glide-path angle, approach rate, and initial positions of the aircraft. Again τ = 2, 4, 6, and 8 sec. These curves, representing the modified approach, are obtained by assuming that the pilot who turns final below the glide path flies straight and level until he zeroes the color sequencing. At this instant he begins to descend so that he maintains a steady color, which turns green as he intercepts glide path. From this graph it is seen that modified programmed flight path is also relatively insensitive to variations in τ. The range at which the pilot first stops the sequencing lights, R_i, decreases by about 0.1 mi as τ is increased by two seconds. The glide-path intercept range R_G decreases in a like manner.

Figure 10 shows the vertical rates experienced by the aircraft on the flight paths of Fig. 9.

Figures 11 and 12 illustrate the effects of airspeed on the approach paths and the vertical rates of aircraft whose pilots are flying the modified approach. The dotted lines represent the paths of aircraft approaching the carrier at a rate of 60 knots, the solid lines the paths of those approaching at 120 knots. Once again, it is apparent that the effects of airspeed on the characteristics of the modified programmed flight path are minimal.

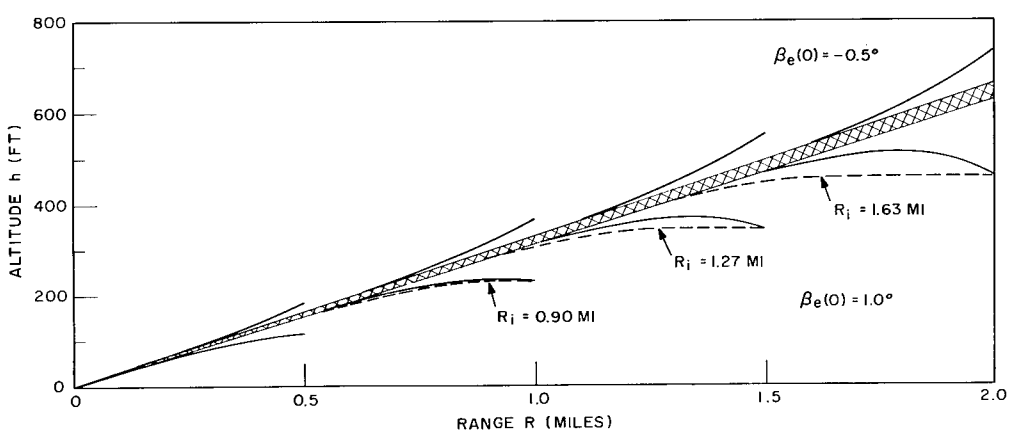

Fig. 13 - Standard (solid line) and modified (dotted line) programmed flight paths. Graph has expanded vertical scale (5:1). $\dot{R}$ = -120 kt; R_0 = 0.5, 1.0, 1.5, 2.0 mi; τ = 6 sec; $\beta_e(0)$ = -0.5°, 1.0°.

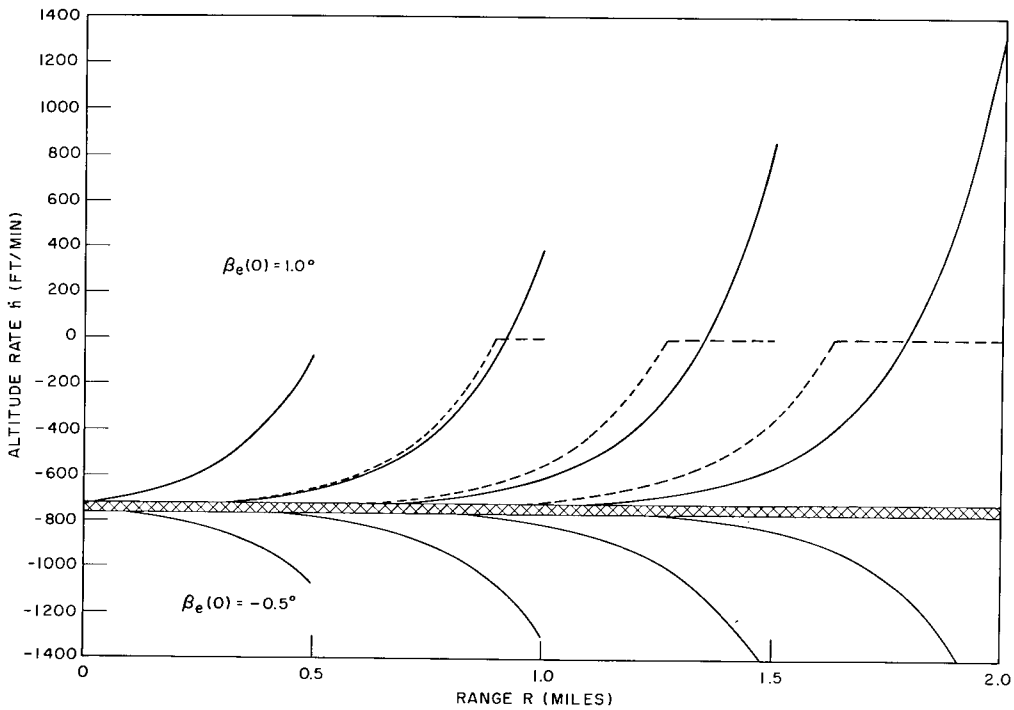

Fig. 14 - Vertical rate $\dot{h} = \dot{h}(R)$ for standard (solid lines) and modified (dotted lines) programmed flight path. Note scale change from Fig. 5. $\dot{R}$ = -120 kt; R_0 = 0.5, 1.0, 1.5, 2.0 mi; τ = 6 sec; $\beta_e(0)$ = -0.5°, 1.0°.

The last two figures, Figs. 13 and 14, display the effect of varying the range R_0 at which the aircraft begins to fly the Rainbow. Values of R_0 = 0.5 mi, 1.0 mi, 1.5 mi, and 2.0 mi are considered. The time constant is τ = 6 sec. On these two graphs, the solid lines represent the paths of aircraft whose pilots fly the unmodified approach – i.e., maintain a constant color at all times, even if this requires climbing; the broken lines represent the paths of those whose pilots fly the modified approach and do not follow the command to climb, but wait until the sequencing stops in straight and level flight. The glide-path intercept ranges are not greatly different for the two types of approach initiated from the same points. However, the vertical rates for the different types of approach are quite different, since one precludes climb by definition and the other, at least for most cases when the aircraft is below glide path, does require climb.

CONCLUSIONS

The following conclusions were made on the basis of such curves as those shown: (a) the optimum projected time constant is τ = 6 sec,* (b) a single pattern is suitable for use by aircraft having different landing speeds, and (c) there is little difference in glide-path intercept range resulting from flying a modified approach to correct an error below glide path rather than that actually commanded by the system.

*This decision was also based on the feasibility of manufacturing the drum pattern, which was complicated by the accuracy required and the extremely narrow colored stripes. Stripe width of course depends not only on time constant and rotation speed but also on the desired basic sequence rate. All these factors were considered in the selection of the optimum time constant.

In almost every case under consideration, the programmed flight paths are relatively insensitive to changes in the projected beam patterns and also to changes in aircraft approach speed. The vertical rates are much more sensitive to changes in these parameters, however, and are therefore the prime factor in the selection of the optimum values. A table of the altitude and vertical rates for approach rates of 60 and 120 knots and $\tau = 6$ sec is given in Appendix C.

ACKNOWLEDGMENT

The authors express their appreciation to Miss Anna Mays of NRL's Research Computation Center, who programmed the equations in this report for the NAREC. The tables of Appendix B are a duplication of the computer output, and such tables were used in plotting the graphs.

REFERENCES

1. Roberts, C.A., "Design Equations for Rainbow Optical Landing Aid," NRL Report 6199, Feb. 1965

2. Perry, B.L., "The Rainbow Optical Landing Aid," NRL Report 6184, Feb. 1965

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APPENDIX A

TWO-COLOR SYSTEM

A question frequently raised regarding the Rainbow system concerns the necessity of having three colors in the sequence. It is pointed out that one two-color sequence, such as blue-white, above the green glide path, and a different two-color sequence, such as red-white, below glide path, would have several distinct advantages over the three-color system.

Instructions to a pilot flying such a two-color system would be as follows: "If the color sequence contains blue, you are high. If the sequence contains red, you are low. Sequencing colors indicate a sink-rate error. A steady color (other than green) indicates an appropriate correction of sink rate." Note the similarity of these commands to those used by the pilot flying the three-color system. The drum pattern for such a two-color system would vary from that of the three-color system only in the coloring of the exponential bands.

There are indeed several advantages in a two-color system over a three-color system. One is the greater ease with which the pilot might learn to interpret the commands of the display. A second, concerned with installation aboard a carrier, is minimal color confusion due to the beam movement introduced by ship motion. The third and perhaps most important advantage, however, is the provision of high-low information to the pilot.

Not to be overlooked is the feasibility of manufacturing the drum pattern selected. Clearly, a two-color transparency would be less complicated to produce than would a three-color one, since a line negative printed in a single color for the top half and a different color for the bottom half would provide the two-color projected pattern.

On the other hand, there are also several disadvantages to the two-color system. The primary one concerns the potential "color-sequence reversals," which are the indication to the pilot of an overcorrection of sink-rate error. A color reversal is, of course, discernible only when the color sequence contains more than two colors, since one does not notice when the red-white-red-white sequence reverses to white-red-white-red. The pilot flying a two-color system with a time constant of 6 or 8 sec who overcorrected his sink-rate error would at best notice only that the color sequencing had speeded up. But this is also percisely the indication of improper correction, or correction in the wrong direction. This ambiguity could clearly lead to serious trouble.

However, this difficulty could be eliminated and the system made workable by a modification to the projected pattern. The time constant could be decreased until beam rate exceeded the vertical rates of an aircraft whose pilot adhered to the structural limitations of his aircraft. As a result, overcorrection would never occur, so color-sequence acceleration would consistently indicate improper correction. In order to eliminate the possibility of overcorrection over a major portion of the approach envelope the time constant would have to be about two seconds. However, decreasing the time constant to this small value simultaneously decreases the gain on the rate-feedback term (2) and thus decreases system damping, which in turn leads to a less stable landing approach.

A possible secondary disadvantage of the two-color system lies in the manner of error-signal encoding. It has been suggested that an alternative color-sequence frequency change

is not as arresting an indication of error correction as is the deceleration of three sequencing colors. Also, the basic sequence rate would have to be higher for the two-color system than for the three-color one. This increased sequence rate could lead to serious problems if it became so high as to approach the alpha brain-wave frequency of the pilot.

The advantages to be gained with the short-time-constant, two-color system are considered not to outweigh the accompanying loss of system damping. For this reason, the three-color system was chosen for initial experimental work. This discussion of the two-color system is included merely to describe one alternative method of color-sequence encoding of rate-error information in conjunction with binary position information where low system damping is tolerable.

APPENDIX B

DERIVATION OF EXPRESSION FOR R_i

When the aircraft is in level flight,

$$h = R_0 (\beta_c - \beta_e(0)) \quad \text{and} \quad \dot{h} = 0.$$

For

$$R_i \geq R \geq 0, \; \dot{h} = \left(\frac{R}{\tau} - \dot{R}\right) \beta_e(t_i) e^{(R_i - R)/\dot{R}\tau} + \dot{R}\, \beta_c.$$

But, by hypothesis, $\dot{h} = 0$ when $R = R_i$

$$\therefore 0 = \left(\frac{R_i}{\tau} - \dot{R}\right) \beta_e(t_i) + \dot{R}\, \beta_c.$$

But, $\beta_c - \beta_e(t_i) = \dfrac{R_0 (\beta_c - \beta_e(0))}{R_i}$

$$\therefore 0 = \left(\frac{R_i}{\tau} - \dot{R}\right) \left[\beta_c - \frac{R_0 (\beta_c - \beta_e(0))}{R_i}\right] + \dot{R}\, \beta_c$$

$$\therefore R_i = \frac{R_0 (\beta_c - \beta_e(0)) \pm \sqrt{R_0^2 (\beta_c - \beta_e(0))^2 - 4\tau \dot{R} R_0 \beta_c (\beta_c - \beta_e(0))}}{2\beta_c}$$

where the greater value of R_i is relevant to this study.

APPENDIX C

TABLES OF VERTICAL RATES FOR 6-SEC PROJECTED TIME CONSTANT

SYMBOL	DEFINITION
R_0	Range at which pilot begins to fly a Rainbow beam. Measured in miles.
R	Instantaneous range from touchdown. Measured in miles.
$\dot{R}$	Approach rate to carrier (negative by definition) -.038359333 mi/sec = -120 knots -.019179667 mi/sec = -60 knots
R_i	Range at which pilot flying modified approach first sees steady color, or first zeroes color sequencing in straight and level flight, below glide path. Measured in miles.
h	Altitude. Measured in feet.
$\dot{h}$	Altitude rate (equivalent to negative of sink rate). Measured in ft/min.
$\beta_e(0)$	Angular error from glide path at range R_0. Measured in degrees. (Note: $\beta_e(0) < 0$ is error <u>above</u> glide path; $\beta_e(0) > 0$ is error <u>below</u> glide path.)
τ	Projected time constant. Measured in seconds. (Defined here as 6 sec.)*

The values for R, h, and $\dot{h}$ are given in floating point.

*Tables for other values of τ are available on request.

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EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: .5

BETA: 2.0

R	H	H DOT
.5000000 +000	.6911504 +002	.6033890 +003
.4000000 +000	.8127219 +002	.9793392 +001
.3000000 +000	.7357264 +002	-.3325553 +003
.2000000 +000	.5449621 +002	-.5270200 +003
.1000000 +000	.2901209 +002	-.6353148 +003
.0000000 +000	.0000000 +000	-.6940226 +003

BETA: 1.5

R	H	H DOT
.5000000 +000	.9215338 +002	.2669573 +003
.4000000 +000	.9320783 +002	-.1782394 +003
.3000000 +000	.7936974 +002	-.4350009 +003
.2000000 +000	.5699900 +002	-.5808495 +003
.1000000 +000	.2982249 +002	-.6620705 +003
.0000000 +000	.0000000 +000	-.7061014 +003

BETA: 1.0

R	H	H DOT
.5000000 +000	.1151917 +003	-.6947443 +002
.4000000 +000	.1051435 +003	-.3662723 +003
.3000000 +000	.8516684 +002	-.5374466 +003
.2000000 +000	.5950179 +002	-.6346789 +003
.1000000 +000	.3063289 +002	-.6888263 +003
.0000000 +000	.0000000 +000	-.7181802 +003

BETA: .5

R	H	H DOT
.5000000 +000	.1382301 +003	-.4059062 +003
.4000000 +000	.1170791 +003	-.5543051 +003
.3000000 +000	.9096395 +002	-.6398922 +003
.2000000 +000	.6200458 +002	-.6885084 +003
.1000000 +000	.3144329 +002	-.7155821 +003
.0000000 +000	.0000000 +000	-.7302591 +003

BETA: -.5

R	H	H DOT
.5000000 +000	.1843068 +003	-.1078770 +004
.4000000 +000	.1409504 +003	-.9303707 +003

.3000000 +000	.1025582 +003	-.8447836 +003
.2000000 +000	.6701016 +002	-.7961674 +003
.1000000 +000	.3306408 +002	-.7690937 +003
.0000000 +000	.0000000 +000	-.7544167 +003

BETA: -1.0

R	H	H DOT
.5000000 +000	.2073451 +003	-.1415201 +004
.4000000 +000	.1528860 +003	-.1118404 +004
.3000000 +000	.1083553 +003	-.9472292 +003
.2000000 +000	.6951295 +002	-.8499969 +003
.1000000 +000	.3387448 +002	-.7958495 +003
.0000000 +000	.0000000 +000	-.7664956 +003

BETA: -1.5

R	H	H DOT
.5000000 +000	.2303835 +003	-.1751633 +004
.4000000 +000	.1648216 +003	-.1306436 +004
.3000000 +000	.1141524 +003	-.1049675 +004
.2000000 +000	.7201574 +002	-.9038263 +003
.1000000 +000	.3468488 +002	-.8226052 +003
.0000000 +000	.0000000 +000	-.7785744 +003

BETA: -2.0

R	H	H DOT
.5000000 +000	.2534218 +003	-.2088065 +004
.4000000 +000	.1767573 +003	-.1494469 +004
.3000000 +000	.1199495 +003	-.1152121 +004
.2000000 +000	.7451852 +002	-.9576558 +003
.1000000 +000	.3549528 +002	-.8493610 +003
.0000000 +000	.0000000 +000	-.7906532 +003

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EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: 1.0

BETA: 2.0

R	H	H DOT
.1000000 +001	.1382301 +003	.1524923 +004
.9000000 +000	.1828624 +003	.6065752 +003
.8000000 +000	.1961937 +003	.5391839 +002
.7000000 +000	.1907368 +003	-.2767411 +003
.6000000 +000	.1740726 +003	-.4732351 +003
.5000000 +000	.1507722 +003	-.5890604 +003
.4000000 +000	.1235769 +003	-.6566706 +003
.3000000 +000	.9411991 +002	-.6956639 +003
.2000000 +000	.6336710 +002	-.7178133 +003
.1000000 +000	.3188447 +002	-.7301480 +003
.0000000 +000	.0000000 +000	-.7368348 +003

BETA: 1.5

R	H	H DOT
.1000000 +001	.1843068 +003	.9581077 +003
.9000000 +000	.2097176 +003	.2693469 +003
.8000000 +000	.2116526 +003	-.1451457 +003
.7000000 +000	.1994965 +003	-.3931403 +003
.6000000 +000	.1789349 +003	-.5405108 +003
.5000000 +000	.1533963 +003	-.6273798 +003
.4000000 +000	.1249364 +003	-.6780874 +003
.3000000 +000	.9478019 +002	-.7073324 +003
.2000000 +000	.6365217 +002	-.7239445 +003
.1000000 +000	.3197677 +002	-.7331955 +003
.0000000 +000	.0000000 +000	-.7382106 +003

BETA: 1.0

R	H	H DOT
.1000000 +001	.2303835 +003	.3912925 +003
.9000000 +000	.2365728 +003	-.6788134 +002
.8000000 +000	.2271116 +003	-.3442098 +003
.7000000 +000	.2082563 +003	-.5095395 +003
.6000000 +000	.1837973 +003	-.6077865 +003
.5000000 +000	.1560203 +003	-.6656991 +003
.4000000 +000	.1262958 +003	-.6995042 +003
.3000000 +000	.9544048 +002	-.7190009 +003
.2000000 +000	.6393724 +002	-.7300756 +003
.1000000 +000	.3206908 +002	-.7362430 +003
.0000000 +000	.0000000 +000	-.7395864 +003

BETA: .5

R	H	H DOT

.1000000 +001	.2764602 +003	-.1755227 +003
.9000000 +000	.2634280 +003	-.4051096 +003
.8000000 +000	.2425705 +003	-.5432738 +003
.7000000 +000	.2170160 +003	-.6259387 +003
.6000000 +000	.1886597 +003	-.6750622 +003
.5000000 +000	.1586444 +003	-.7040185 +003
.4000000 +000	.1276553 +003	-.7209211 +003
.3000000 +000	.9610077 +002	-.7306694 +003
.2000000 +000	.6422230 +002	-.7362068 +003
.1000000 +000	.3216138 +002	-.7392904 +003
.0000000 +000	.0000000 +000	-.7409621 +003

BETA: -.5

R	H	H DOT
.1000000 +001	.3686135 +003	-.1309153 +004
.9000000 +000	.3171383 +003	-.1079566 +004
.8000000 +000	.2734884 +003	-.9414020 +003
.7000000 +000	.2345356 +003	-.8587371 +003
.6000000 +000	.1983845 +003	-.8096136 +003
.5000000 +000	.1638925 +003	-.7806573 +003
.4000000 +000	.1303742 +003	-.7637547 +003
.3000000 +000	.9742134 +002	-.7540064 +003
.2000000 +000	.6479244 +002	-.7484690 +003
.1000000 +000	.3234599 +002	-.7453854 +003
.0000000 +000	.0000000 +000	-.7437137 +003

BETA: -1.0

R	H	H DOT
.1000000 +001	.4146902 +003	-.1875968 +004
.9000000 +000	.3439935 +003	-.1416794 +004
.8000000 +000	.2889474 +003	-.1140466 +004
.7000000 +000	.2432953 +003	-.9751363 +003
.6000000 +000	.2032469 +003	-.8768893 +003
.5000000 +000	.1665165 +003	-.8189766 +003
.4000000 +000	.1317337 +003	-.7851716 +003
.3000000 +000	.9808163 +002	-.7656749 +003
.2000000 +000	.6507750 +002	-.7546002 +003
.1000000 +000	.3243829 +002	-.7484328 +003
.0000000 +000	.0000000 +000	-.7450894 +003

BETA: -1.5

R	H	H DOT
.1000000 +001	.4607669 +003	-.2442783 +004
.9000000 +000	.3708487 +003	-.1754023 +004
.8000000 +000	.3044063 +003	-.1339530 +004
.7000000 +000	.2520551 +003	-.1091535 +004
.6000000 +000	.2081093 +003	-.9441650 +003
.5000000 +000	.1691406 +003	-.8572960 +003
.4000000 +000	.1330931 +003	-.8065884 +003
.3000000 +000	.9874191 +002	-.7773434 +003

.2000000 +000	.6536257 +002	-.7607313 +003
.1000000 +000	.3253060 +002	-.7514803 +003
.0000000 +000	.0000000 +000	-.7464652 +003

BETA: -2.0

R	H	H DOT
.1000000 +001	.5068436 +003	-.3009599 +004
.9000000 +000	.3977039 +003	-.2091251 +004
.8000000 +000	.3198653 +003	-.1538594 +004
.7000000 +000	.2608148 +003	-.1207935 +004
.6000000 +000	.2129717 +003	-.1011441 +004
.5000000 +000	.1717646 +003	-.8956154 +003
.4000000 +000	.1344526 +003	-.8280052 +003
.3000000 +000	.9940220 +002	-.7890119 +003
.2000000 +000	.6564763 +002	-.7668625 +003
.1000000 +000	.3262290 +002	-.7545278 +003
.0000000 +000	.0000000 +000	-.7478410 +003

EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: 1.5

BETA: 2.0

R	H	H DOT
.1500000 +001	.2073451 +003	.2446457 +004
.1400000 +001	.2844527 +003	.1203357 +004
.1300000 +001	.3188148 +003	.4403920 +003
.1200000 +001	.3269773 +003	-.2646226 +002
.1100000 +001	.3191330 +003	-.3111555 +003
.1000000 +001	.3015444 +003	-.4840982 +003
.9000000 +000	.2780480 +003	-.5886975 +003
.8000000 +000	.2509864 +003	-.6516448 +003
.7000000 +000	.2217849 +003	-.6893067 +003
.6000000 +000	.1913068 +003	-.7116872 +003
.5000000 +000	.1600729 +003	-.7248797 +003
.4000000 +000	.1283954 +003	-.7325804 +003
.3000000 +000	.9646023 +002	-.7370218 +003
.2000000 +000	.6437749 +002	-.7395446 +003
.1000000 +000	.3221163 +002	-.7409495 +003
.0000000 +000	.0000000 +000	-.7417111 +003

BETA: 1.5

R	H	H DOT
.1500000 +001	.2764602 +003	.1649258 +004
.1400000 +001	.3262274 +003	.7169333 +003
.1300000 +001	.3439355 +003	.1447095 +003
.1200000 +001	.3419940 +003	-.2054312 +003
.1100000 +001	.3280474 +003	-.4189511 +003
.1000000 +001	.3067925 +003	-.5486581 +003
.9000000 +000	.2811068 +003	-.6271076 +003
.8000000 +000	.2527472 +003	-.6743181 +003
.7000000 +000	.2227826 +003	-.7025645 +003
.6000000 +000	.1918606 +003	-.7193499 +003
.5000000 +000	.1603718 +003	-.7292442 +003
.4000000 +000	.1285502 +003	-.7350198 +003
.3000000 +000	.9653543 +002	-.7383508 +003
.2000000 +000	.6440996 +002	-.7402429 +003
.1000000 +000	.3222214 +002	-.7412966 +003
.0000000 +000	.0000000 +000	-.7418678 +003

BETA: 1.0

R	H	H DOT
.1500000 +001	.3455752 +003	.8520594 +003
.1400000 +001	.3680021 +003	.2305096 +003
.1300000 +001	.3690563 +003	-.1509729 +003
.1200000 +001	.3570108 +003	-.3844001 +003
.1100000 +001	.3369618 +003	-.5267467 +003
.1000000 +001	.3120406 +003	-.6132181 +003

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.9000000 +000	.2841656 +003	-.6655177 +003
.8000000 +000	.2545079 +003	-.6969913 +003
.7000000 +000	.2237803 +003	-.7158223 +003
.6000000 +000	.1924145 +003	-.7270126 +003
.5000000 +000	.1606707 +003	-.7336088 +003
.4000000 +000	.1287051 +003	-.7374592 +003
.3000000 +000	.9661064 +002	-.7396798 +003
.2000000 +000	.6444243 +002	-.7409412 +003
.1000000 +000	.3223266 +002	-.7416437 +003
.0000000 +000	.0000000 +000	-.7420245 +003

BETA: .5

R	H	H DOT
.1500000 +001	.4146902 +003	.5486076 +002
.1400000 +001	.4097769 +003	-.2559142 +003
.1300000 +001	.3941771 +003	-.4466554 +003
.1200000 +001	.3720275 +003	-.5633690 +003
.1100000 +001	.3458761 +003	-.6345423 +003
.1000000 +001	.3172887 +003	-.6777780 +003
.9000000 +000	.2872244 +003	-.7039278 +003
.8000000 +000	.2562687 +003	-.7196646 +003
.7000000 +000	.2247781 +003	-.7290801 +003
.6000000 +000	.1929683 +003	-.7346752 +003
.5000000 +000	.1609695 +003	-.7379733 +003
.4000000 +000	.1288599 +003	-.7398985 +003
.3000000 +000	.9668585 +002	-.7410089 +003
.2000000 +000	.6447490 +002	-.7416396 +003
.1000000 +000	.3224317 +002	-.7419908 +003
.0000000 +000	.0000000 +000	-.7421812 +003

BETA: -.5

R	H	H DOT
.1500000 +001	.5529203 +003	-.1539537 +004
.1400000 +001	.4933263 +003	-.1228762 +004
.1300000 +001	.4444187 +003	-.1038020 +004
.1200000 +001	.4020609 +003	-.9213068 +003
.1100000 +001	.3637049 +003	-.8501335 +003
.1000000 +001	.3277850 +003	-.8068978 +003
.9000000 +000	.2933420 +003	-.7807480 +003
.8000000 +000	.2597902 +003	-.7650112 +003
.7000000 +000	.2267735 +003	-.7555957 +003
.6000000 +000	.1940759 +003	-.7500006 +003
.5000000 +000	.1615673 +003	-.7467025 +003
.4000000 +000	.1291696 +003	-.7447773 +003
.3000000 +000	.9683626 +002	-.7436669 +003
.2000000 +000	.6453984 +002	-.7430362 +003
.1000000 +000	.3226420 +002	-.7426850 +003
.0000000 +000	.0000000 +000	-.7424946 +003

BETA: -1.0

R	H	H DOT

.1500000 +001	.6220353 +003	-.2336735 +004
.1400000 +001	.5351010 +003	-.1715185 +004
.1300000 +001	.4695395 +003	-.1333703 +004
.1200000 +001	.4170777 +003	-.1100276 +004
.1100000 +001	.3726193 +003	-.9579291 +003
.1000000 +001	.3330331 +003	-.8714577 +003
.9000000 +000	.2964007 +003	-.8191581 +003
.8000000 +000	.2615510 +003	-.7876845 +003
.7000000 +000	.2277713 +003	-.7688535 +003
.6000000 +000	.1946298 +003	-.7576632 +003
.5000000 +000	.1618662 +003	-.7510670 +003
.4000000 +000	.1293244 +003	-.7472166 +003
.3000000 +000	.9691147 +002	-.7449960 +003
.2000000 +000	.6457231 +002	-.7437346 +003
.1000000 +000	.3227471 +002	-.7430321 +003
.0000000 +000	.0000000 +000	-.7426513 +003

BETA: -1.5

R	H	H DOT
.1500000 +001	.6911504 +003	-.3133934 +004
.1400000 +001	.5768758 +003	-.2201609 +004
.1300000 +001	.4946603 +003	-.1629385 +004
.1200000 +001	.4320944 +003	-.1279245 +004
.1100000 +001	.3815337 +003	-.1065725 +004
.1000000 +001	.3382812 +003	-.9360176 +003
.9000000 +000	.2994595 +003	-.8575682 +003
.8000000 +000	.2633118 +003	-.8103577 +003
.7000000 +000	.2287690 +003	-.7821113 +003
.6000000 +000	.1951836 +003	-.7653259 +003
.5000000 +000	.1621651 +003	-.7554316 +003
.4000000 +000	.1294793 +003	-.7496560 +003
.3000000 +000	.9698667 +002	-.7463250 +003
.2000000 +000	.6460478 +002	-.7444329 +003
.1000000 +000	.3228522 +002	-.7433792 +003
.0000000 +000	.0000000 +000	-.7428080 +003

BETA: -2.0

R	H	H DOT
.1500000 +001	.7602654 +003	-.3931133 +004
.1400000 +001	.6186505 +003	-.2688033 +004
.1300000 +001	.5197810 +003	-.1925068 +004
.1200000 +001	.4471111 +003	-.1458214 +004
.1100000 +001	.3904481 +003	-.1173520 +004
.1000000 +001	.3435293 +003	-.1000578 +004
.9000000 +000	.3025183 +003	-.8959783 +003
.8000000 +000	.2650725 +003	-.8330310 +003
.7000000 +000	.2297667 +003	-.7953691 +003
.6000000 +000	.1957374 +003	-.7729885 +003
.5000000 +000	.1624639 +003	-.7597961 +003
.4000000 +000	.1296341 +003	-.7520954 +003
.3000000 +000	.9706188 +002	-.7476540 +003
.2000000 +000	.6463724 +002	-.7451312 +003
.1000000 +000	.3229574 +002	-.7437263 +003
.0000000 +000	.0000000 +000	-.7429647 +003

UNCLASSIFIED

EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: 2.0

BETA: 2.0

R	H	H DOT
.2000000 +001	.2764602 +003	.3367991 +004
.1900000 +001	.3860429 +003	.1800139 +004
.1800000 +001	.4414358 +003	.8268657 +003
.1700000 +001	.4632178 +003	.2238166 +003
.1600000 +001	.4641935 +003	-.1490758 +003
.1500000 +001	.4523166 +003	-.3791361 +003
.1400000 +001	.4325191 +003	-.5207244 +003
.1300000 +001	.4078529 +003	-.6076257 +003
.1200000 +001	.3802026 +003	-.6608001 +003
.1100000 +001	.3507292 +003	-.6932265 +003
.1000000 +001	.3201458 +003	-.7129246 +003
.9000000 +000	.2888896 +003	-.7248383 +003
.8000000 +000	.2572273 +003	-.7320080 +003
.7000000 +000	.2253212 +003	-.7362977 +003
.6000000 +000	.1932698 +003	-.7388468 +003
.5000000 +000	.1611323 +003	-.7403494 +003
.4000000 +000	.1289442 +003	-.7412265 +003
.3000000 +000	.9672679 +002	-.7417324 +003
.2000000 +000	.6449258 +002	-.7420197 +003
.1000000 +000	.3224889 +002	-.7421798 +003
.0000000 +000	.0000000 +000	-.7422665 +003

BETA: 1.5

R	H	H DOT
.2000000 +001	.3686135 +003	.2340408 +004
.1900000 +001	.4427372 +003	.1164520 +004
.1800000 +001	.4762184 +003	.4345648 +003
.1700000 +001	.4844915 +003	-.1772202 +002
.1600000 +001	.4771598 +003	-.2973913 +003
.1500000 +001	.4601888 +003	-.4699365 +003
.1400000 +001	.4372772 +003	-.5761278 +003
.1300000 +001	.4107142 +003	-.6413037 +003
.1200000 +001	.3819130 +003	-.6811845 +003
.1100000 +001	.3517445 +003	-.7055043 +003
.1000000 +001	.3207436 +003	-.7202779 +003
.9000000 +000	.2892380 +003	-.7292132 +003
.8000000 +000	.2574278 +003	-.7345905 +003
.7000000 +000	.2254349 +003	-.7378077 +003
.6000000 +000	.1933329 +003	-.7397196 +003
.5000000 +000	.1611663 +003	-.7408465 +003
.4000000 +000	.1289618 +003	-.7415044 +003
.3000000 +000	.9673536 +002	-.7418838 +003
.2000000 +000	.6449627 +002	-.7420993 +003
.1000000 +000	.3225009 +002	-.7422193 +003
.0000000 +000	.0000000 +000	-.7422844 +003

BETA: 1.0

R	H	H DOT
.2000000 +001	.4607669 +003	.1312826 +004
.1900000 +001	.4994315 +003	.5289005 +003
.1800000 +001	.5110011 +003	.4226389 +002
.1700000 +001	.5057652 +003	-.2592606 +003
.1600000 +001	.4901262 +003	-.4457069 +003
.1500000 +001	.4680609 +003	-.5607370 +003
.1400000 +001	.4420354 +003	-.6315311 +003
.1300000 +001	.4135754 +003	-.6749818 +003
.1200000 +001	.3836234 +003	-.7015690 +003
.1100000 +001	.3527598 +003	-.7177822 +003
.1000000 +001	.3213413 +003	-.7276312 +003
.9000000 +000	.2895864 +003	-.7335881 +003
.8000000 +000	.2576284 +003	-.7371729 +003
.7000000 +000	.2255485 +003	-.7393178 +003
.6000000 +000	.1933959 +003	-.7405924 +003
.5000000 +000	.1612003 +003	-.7413437 +003
.4000000 +000	.1289795 +003	-.7417822 +003
.3000000 +000	.9674392 +002	-.7420351 +003
.2000000 +000	.6449997 +002	-.7421788 +003
.1000000 +000	.3225129 +002	-.7422588 +003
.0000000 +000	.0000000 +000	-.7423022 +003

BETA: .5

R	H	H DOT
.2000000 +001	.5529203 +003	.2852442 +003
.1900000 +001	.5561257 +003	-.1067187 +003
.1800000 +001	.5457837 +003	-.3500370 +003
.1700000 +001	.5270389 +003	-.5007993 +003
.1600000 +001	.5030926 +003	-.5940224 +003
.1500000 +001	.4759331 +003	-.6515374 +003
.1400000 +001	.4467935 +003	-.6869345 +003
.1300000 +001	.4164367 +003	-.7086598 +003
.1200000 +001	.3853338 +003	-.7219534 +003
.1100000 +001	.3537752 +003	-.7300600 +003
.1000000 +001	.3219391 +003	-.7349846 +003
.9000000 +000	.2899348 +003	-.7379630 +003
.8000000 +000	.2578289 +003	-.7397554 +003
.7000000 +000	.2256622 +003	-.7408278 +003
.6000000 +000	.1934590 +003	-.7414651 +003
.5000000 +000	.1612344 +003	-.7418408 +003
.4000000 +000	.1289971 +003	-.7420601 +003
.3000000 +000	.9675249 +002	-.7421865 +003
.2000000 +000	.6450367 +002	-.7422584 +003
.1000000 +000	.3225249 +002	-.7422984 +003
.0000000 +000	.0000000 +000	-.7423200 +003

BETA: -.5

R	H	H DOT
.2000000 +001	.7372271 +003	-.1769920 +004
.1900000 +001	.6695143 +003	-.1377957 +004

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.1800000 +001	.6153490 +003	-.1134639 +004
.1700000 +001	.5695863 +003	-.9838765 +003
.1600000 +001	.5290253 +003	-.8906534 +003
.1500000 +001	.4916774 +003	-.8331384 +003
.1400000 +001	.4563097 +003	-.7977413 +003
.1300000 +001	.4221591 +003	-.7760160 +003
.1200000 +001	.3887546 +003	-.7627223 +003
.1100000 +001	.3558059 +003	-.7546158 +003
.1000000 +001	.3231346 +003	-.7496912 +003
.9000000 +000	.2906316 +003	-.7467128 +003
.8000000 +000	.2582300 +003	-.7449204 +003
.7000000 +000	.2258894 +003	-.7438480 +003
.6000000 +000	.1935852 +003	-.7432107 +003
.5000000 +000	.1613025 +003	-.7428350 +003
.4000000 +000	.1290324 +003	-.7426157 +003
.3000000 +000	.9676962 +002	-.7424893 +003
.2000000 +000	.6451107 +002	-.7424174 +003
.1000000 +000	.3225488 +002	-.7423774 +003
.0000000 +000	.0000000 +000	-.7423557 +003

BETA: -1.0

R	H	H DOT
.2000000 +001	.8293805 +003	-.2797502 +004
.1900000 +001	.7262086 +003	-.2013576 +004
.1800000 +001	.6501316 +003	-.1526940 +004
.1700000 +001	.5908600 +003	-.1225415 +004
.1600000 +001	.5419917 +003	-.1038969 +004
.1500000 +001	.4995496 +003	-.9239388 +003
.1400000 +001	.4610678 +003	-.8531446 +003
.1300000 +001	.4250204 +003	-.8096940 +003
.1200000 +001	.3904650 +003	-.7831068 +003
.1100000 +001	.3568212 +003	-.7668936 +003
.1000000 +001	.3237324 +003	-.7570446 +003
.9000000 +000	.2909799 +003	-.7510877 +003
.8000000 +000	.2584306 +003	-.7475028 +003
.7000000 +000	.2260031 +003	-.7453580 +003
.6000000 +000	.1936483 +003	-.7440834 +003
.5000000 +000	.1613365 +003	-.7433321 +003
.4000000 +000	.1290500 +003	-.7428936 +003
.3000000 +000	.9677819 +002	-.7426406 +003
.2000000 +000	.6451477 +002	-.7424970 +003
.1000000 +000	.3225608 +002	-.7424170 +003
.0000000 +000	.0000000 +000	-.7423736 +003

BETA: -1.5

R	H	H DOT
.2000000 +001	.9215338 +003	-.3825084 +004
.1900000 +001	.7829028 +003	-.2649195 +004
.1800000 +001	.6849142 +003	-.1919241 +004
.1700000 +001	.6121337 +003	-.1466954 +004
.1600000 +001	.5549581 +003	-.1187284 +004
.1500000 +001	.5074218 +003	-.1014739 +004
.1400000 +001	.4658259 +003	-.9085480 +003
.1300000 +001	.4278816 +003	-.8433721 +003

.1200000 +001	.3921754 +003	-.8034913 +003
.1100000 +001	.3578366 +003	-.7791715 +003
.1000000 +001	.3243301 +003	-.7643979 +003
.9000000 +000	.2913283 +003	-.7554626 +003
.8000000 +000	.2586311 +003	-.7500853 +003
.7000000 +000	.2261167 +003	-.7468681 +003
.6000000 +000	.1937113 +003	-.7449562 +003
.5000000 +000	.1613705 +003	-.7438293 +003
.4000000 +000	.1290676 +003	-.7431714 +003
.3000000 +000	.9678675 +002	-.7427920 +003
.2000000 +000	.6451846 +002	-.7425765 +003
.1000000 +000	.3225728 +002	-.7424565 +003
.0000000 +000	.0000000 +000	-.7423914 +003

BETA: -2.0

R	H	H DOT
.2000000 +001	.1013687 +004	-.4852666 +004
.1900000 +001	.8395971 +003	-.3284815 +004
.1800000 +001	.7196968 +003	-.2311541 +004
.1700000 +001	.6334075 +003	-.1708492 +004
.1600000 +001	.5679244 +003	-.1335600 +004
.1500000 +001	.5152939 +003	-.1105540 +004
.1400000 +001	.4705841 +003	-.9639514 +003
.1300000 +001	.4307429 +003	-.8770501 +003
.1200000 +001	.3938858 +003	-.8238757 +003
.1100000 +001	.3588519 +003	-.7914493 +003
.1000000 +001	.3249279 +003	-.7717512 +003
.9000000 +000	.2916767 +003	-.7598374 +003
.8000000 +000	.2588317 +003	-.7526678 +003
.7000000 +000	.2262304 +003	-.7483781 +003
.6000000 +000	.1937744 +003	-.7458290 +003
.5000000 +000	.1614046 +003	-.7443264 +003
.4000000 +000	.1290853 +003	-.7434493 +003
.3000000 +000	.9679532 +002	-.7429434 +003
.2000000 +000	.6452216 +002	-.7426561 +003
.1000000 +000	.3225847 +002	-.7424960 +003
.0000000 +000	.0000000 +000	-.7424093 +003

UNCLASSIFIED

EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: .5

BETA: 2.0

R	H	H DOT
.5000000 +000	.6911504 +002	.7624614 +003
.4000000 +000	.9809685 +002	.2695920 +002
.3000000 +000	.8703627 +002	-.2366176 +003
.2000000 +000	.6178845 +002	-.3283353 +003
.1000000 +000	.3168355 +002	-.3589067 +003
.0000000 +000	.0000000 +000	-.3684174 +003

BETA: 1.5

R	H	H DOT
.5000000 +000	.9215338 +002	.4790538 +003
.4000000 +000	.1058263 +003	-.7257284 +002
.3000000 +000	.8946747 +002	-.2702554 +003
.2000000 +000	.6246818 +002	-.3390437 +003
.1000000 +000	.3182609 +002	-.3619722 +003
.0000000 +000	.0000000 +000	-.3691053 +003

BETA: 1.0

R	H	H DOT
.5000000 +000	.1151917 +003	.1956462 +003
.4000000 +000	.1135558 +003	-.1721049 +003
.3000000 +000	.9189866 +002	-.3038933 +003
.2000000 +000	.6314791 +002	-.3497521 +003
.1000000 +000	.3196862 +002	-.3650378 +003
.0000000 +000	.0000000 +000	-.3697932 +003

BETA: .5

R	H	H DOT
.5000000 +000	.1382301 +003	-.8776136 +002
.4000000 +000	.1212853 +003	-.2716369 +003
.3000000 +000	.9432986 +002	-.3375311 +003
.2000000 +000	.6382764 +002	-.3604605 +003
.1000000 +000	.3211115 +002	-.3681034 +003
.0000000 +000	.0000000 +000	-.3704811 +003

BETA: -.5

R	H	H DOT
.5000000 +000	.1843068 +003	-.6545766 +003
.4000000 +000	.1367442 +003	-.4707010 +003

.3000000 +000	.9919225 +002	-.4048068 +003
.2000000 +000	.6518710 +002	-.3818774 +003
.1000000 +000	.3239622 +002	-.3742345 +003
.0000000 +000	.0000000 +000	-.3718568 +003

BETA: -1.0

R	H	H DOT
.5000000 +000	.2073451 +003	-.9379842 +003
.4000000 +000	.1444737 +003	-.5702330 +003
.3000000 +000	.1016234 +003	-.4384447 +003
.2000000 +000	.6586683 +002	-.3925858 +003
.1000000 +000	.3253875 +002	-.3773001 +003
.0000000 +000	.0000000 +000	-.3725447 +003

BETA: -1.5

R	H	H DOT
.5000000 +000	.2303835 +003	-.1221392 +004
.4000000 +000	.1522032 +003	-.6697651 +003
.3000000 +000	.1040546 +003	-.4720825 +003
.2000000 +000	.6654656 +002	-.4032942 +003
.1000000 +000	.3268128 +002	-.3803657 +003
.0000000 +000	.0000000 +000	-.3732326 +003

BETA: -2.0

R	H	H DOT
.5000000 +000	.2534218 +003	-.1504799 +004
.4000000 +000	.1599326 +003	-.7692971 +003
.3000000 +000	.1064858 +003	-.5057204 +003
.2000000 +000	.6722629 +002	-.4140026 +003
.1000000 +000	.3282382 +002	-.3834313 +003
.0000000 +000	.0000000 +000	-.3739205 +003

EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: 1.0

BETA: 2.0

R	H	H DOT
.1000000 +001	.1382301 +003	.1683995 +004
.9000000 +000	.2207179 +003	.4134328 +003
.8000000 +000	.2320967 +003	-.7453791 +002
.7000000 +000	.2162596 +003	-.2603622 +003
.6000000 +000	.1901013 +003	-.3304000 +003
.5000000 +000	.1600729 +003	-.3564623 +003
.4000000 +000	.1286136 +003	-.3660040 +003
.3000000 +000	.9663489 +002	-.3694234 +003
.2000000 +000	.6447210 +002	-.3706133 +003
.1000000 +000	.3224629 +002	-.3710099 +003
.0000000 +000	.0000000 +000	-.3711333 +003

BETA: 1.5

R	H	H DOT
.1000000 +001	.1843068 +003	.1170204 +004
.9000000 +000	.2381092 +003	.2172824 +003
.8000000 +000	.2385799 +003	-.1486957 +003
.7000000 +000	.2186386 +003	-.2880639 +003
.6000000 +000	.1909565 +003	-.3405923 +003
.5000000 +000	.1603718 +003	-.3601390 +003
.4000000 +000	.1287139 +003	-.3672952 +003
.3000000 +000	.9666643 +002	-.3698598 +003
.2000000 +000	.6448091 +002	-.3707522 +003
.1000000 +000	.3224814 +002	-.3710496 +003
.0000000 +000	.0000000 +000	-.3711422 +003

BETA: 1.0

R	H	H DOT
.1000000 +001	.2303835 +003	.6564132 +003
.9000000 +000	.2555005 +003	.2113194 +002
.8000000 +000	.2450631 +003	-.2228534 +003
.7000000 +000	.2210177 +003	-.3157656 +003
.6000000 +000	.1918117 +003	-.3507845 +003
.5000000 +000	.1606707 +003	-.3638156 +003
.4000000 +000	.1288142 +003	-.3685865 +003
.3000000 +000	.9669797 +002	-.3702962 +003
.2000000 +000	.6448973 +002	-.3708911 +003
.1000000 +000	.3224999 +002	-.3710894 +003
.0000000 +000	.0000000 +000	-.3711511 +003

BETA: .5

R	H	H DOT

.1000000 +001	.2764602 +003	.1426221 +003
.9000000 +000	.2728918 +003	-.1750185 +003
.8000000 +000	.2515463 +003	-.2970112 +003
.7000000 +000	.2233967 +003	-.3434673 +003
.6000000 +000	.1926669 +003	-.3609767 +003
.5000000 +000	.1609695 +003	-.3674923 +003
.4000000 +000	.1289145 +003	-.3698777 +003
.3000000 +000	.9672951 +002	-.3707326 +003
.2000000 +000	.6449855 +002	-.3710300 +003
.1000000 +000	.3225184 +002	-.3711292 +003
.0000000 +000	.0000000 +000	-.3711600 +003

BETA: -.5

R	H	H DOT
.1000000 +001	.3686135 +003	-.8849600 +003
.9000000 +000	.3076745 +003	-.5673194 +003
.8000000 +000	.2645127 +003	-.4453267 +003
.7000000 +000	.2281549 +003	-.3988706 +003
.6000000 +000	.1943773 +003	-.3813612 +003
.5000000 +000	.1615673 +003	-.3748456 +003
.4000000 +000	.1291150 +003	-.3724602 +003
.3000000 +000	.9679259 +002	-.3716053 +003
.2000000 +000	.6451619 +002	-.3713079 +003
.1000000 +000	.3225553 +002	-.3712087 +003
.0000000 +000	.0000000 +000	-.3711779 +003

BETA: -1.0

R	H	H DOT
.1000000 +001	.4146902 +003	-.1398751 +004
.9000000 +000	.3250658 +003	-.7634699 +003
.8000000 +000	.2709958 +003	-.5194845 +003
.7000000 +000	.2305339 +003	-.4265723 +003
.6000000 +000	.1952325 +003	-.3915534 +003
.5000000 +000	.1618662 +003	-.3785223 +003
.4000000 +000	.1292153 +003	-.3737514 +003
.3000000 +000	.9682413 +002	-.3720417 +003
.2000000 +000	.6452501 +002	-.3714468 +003
.1000000 +000	.3225738 +002	-.3712485 +003
.0000000 +000	.0000000 +000	-.3711868 +003

BETA: -1.5

R	H	H DOT
.1000000 +001	.4607669 +003	-.1912542 +004
.9000000 +000	.3424571 +003	-.9596203 +003
.8000000 +000	.2774790 +003	-.5936422 +003
.7000000 +000	.2329130 +003	-.4542740 +003
.6000000 +000	.1960877 +003	-.4017456 +003
.5000000 +000	.1621651 +003	-.3821990 +003
.4000000 +000	.1293156 +003	-.3750427 +003
.3000000 +000	.9685567 +002	-.3724781 +003

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.2000000 +000	.6453382 +002	-.3715857 +003
.1000000 +000	.3225923 +002	-.3712883 +003
.0000000 +000	.0000000 +000	-.3711957 +003

BETA: -2.0

R	H	H DOT
.1000000 +001	.5068436 +003	-.2426333 +004
.9000000 +000	.3598484 +003	-.1155771 +004
.8000000 +000	.2839622 +003	-.6678000 +003
.7000000 +000	.2352920 +003	-.4819757 +003
.6000000 +000	.1969429 +003	-.4119379 +003
.5000000 +000	.1624639 +003	-.3858756 +003
.4000000 +000	.1294158 +003	-.3763339 +003
.3000000 +000	.9688721 +002	-.3729145 +003
.2000000 +000	.6454264 +002	-.3717246 +003
.1000000 +000	.3226108 +002	-.3713280 +003
.0000000 +000	.0000000 +000	-.3712047 +003

EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: 1.5

BETA: 2.0

R	H	H DOT
.1500000 +001	.2073451 +003	.2605529 +004
.1400000 +001	.3433390 +003	.7999065 +003
.1300000 +001	.3771572 +003	.8754174 +002
.1200000 +001	.3707307 +003	-.1923891 +003
.1100000 +001	.3485191 +003	-.3018934 +003
.1000000 +001	.3201458 +003	-.3445072 +003
.9000000 +000	.2893807 +003	-.3609903 +003
.8000000 +000	.2576930 +003	-.3673207 +003
.7000000 +000	.2256523 +003	-.3697315 +003
.6000000 +000	.1934777 +003	-.3706401 +003
.5000000 +000	.1612529 +003	-.3709782 +003
.4000000 +000	.1290095 +003	-.3711020 +003
.3000000 +000	.9675942 +002	-.3711463 +003
.2000000 +000	.6450691 +002	-.3711617 +003
.1000000 +000	.3225359 +002	-.3711669 +003
.0000000 +000	.0000000 +000	-.3711685 +003

BETA: 1.5

R	H	H DOT
.1500000 +001	.2764602 +003	.1861355 +004
.1400000 +001	.3703921 +003	.5071376 +003
.1300000 +001	.3876924 +003	-.2713594 +002
.1200000 +001	.3748091 +003	-.2370841 +003
.1100000 +001	.3500869 +003	-.3192123 +003
.1000000 +001	.3207436 +003	-.3511726 +003
.9000000 +000	.2896063 +003	-.3635349 +003
.8000000 +000	.2577772 +003	-.3682828 +003
.7000000 +000	.2256832 +003	-.3700908 +003
.6000000 +000	.1934888 +003	-.3707723 +003
.5000000 +000	.1612568 +003	-.3710259 +003
.4000000 +000	.1290108 +003	-.3711187 +003
.3000000 +000	.9675983 +002	-.3711520 +003
.2000000 +000	.6450703 +002	-.3711636 +003
.1000000 +000	.3225361 +002	-.3711674 +003
.0000000 +000	.0000000 +000	-.3711686 +003

BETA: 1.0

R	H	H DOT
.1500000 +001	.3455752 +003	.1117180 +004
.1400000 +001	.3974453 +003	.2143688 +003
.1300000 +001	.3982275 +003	-.1418136 +003
.1200000 +001	.3788874 +003	-.2817790 +003
.1100000 +001	.3516548 +003	-.3365312 +003
.1000000 +001	.3213413 +003	-.3578381 +003

.9000000 +000	.2898319 +003	-.3660796 +003
.8000000 +000	.2578613 +003	-.3692448 +003
.7000000 +000	.2257141 +003	-.3704502 +003
.6000000 +000	.1934999 +003	-.3709045 +003
.5000000 +000	.1612607 +003	-.3710736 +003
.4000000 +000	.1290121 +003	-.3711355 +003
.3000000 +000	.9676024 +002	-.3711576 +003
.2000000 +000	.6450714 +002	-.3711654 +003
.1000000 +000	.3225364 +002	-.3711679 +003
.0000000 +000	.0000000 +000	-.3711687 +003

BETA: .5

R	H	H DOT
.1500000 +001	.4146902 +003	.3730056 +003
.1400000 +001	.4244984 +003	-.7840009 +002
.1300000 +001	.4087627 +003	-.2564913 +003
.1200000 +001	.3829658 +003	-.3264740 +003
.1100000 +001	.3532227 +003	-.3538501 +003
.1000000 +001	.3219391 +003	-.3645035 +003
.9000000 +000	.2900575 +003	-.3686243 +003
.8000000 +000	.2579454 +003	-.3702069 +003
.7000000 +000	.2257449 +003	-.3708096 +003
.6000000 +000	.1935110 +003	-.3710367 +003
.5000000 +000	.1612645 +003	-.3711213 +003
.4000000 +000	.1290134 +003	-.3711522 +003
.3000000 +000	.9676064 +002	-.3711633 +003
.2000000 +000	.6450725 +002	-.3711672 +003
.1000000 +000	.3225366 +002	-.3711684 +003
.0000000 +000	.0000000 +000	-.3711688 +003

BETA: -.5

R	H	H DOT
.1500000 +001	.5529203 +003	-.1115343 +004
.1400000 +001	.4786047 +003	-.6639378 +003
.1300000 +001	.4298331 +003	-.4858466 +003
.1200000 +001	.3911226 +003	-.4158639 +003
.1100000 +001	.3563584 +003	-.3884878 +003
.1000000 +001	.3231346 +003	-.3778344 +003
.9000000 +000	.2905088 +003	-.3737136 +003
.8000000 +000	.2581136 +003	-.3721310 +003
.7000000 +000	.2258067 +003	-.3715283 +003
.6000000 +000	.1935332 +003	-.3713012 +003
.5000000 +000	.1612723 +003	-.3712167 +003
.4000000 +000	.1290160 +003	-.3711857 +003
.3000000 +000	.9676146 +002	-.3711746 +003
.2000000 +000	.6450748 +002	-.3711708 +003
.1000000 +000	.3225371 +002	-.3711695 +003
.0000000 +000	.0000000 +000	-.3711691 +003

BETA: -1.0

R	H	H DOT

.1500000 +001	.6220353 +003	-.1859518 +004
.1400000 +001	.5056579 +003	-.9567067 +003
.1300000 +001	.4403683 +003	-.6005243 +003
.1200000 +001	.3952010 +003	-.4605589 +003
.1100000 +001	.3579263 +003	-.4058067 +003
.1000000 +001	.3237324 +003	-.3844999 +003
.9000000 +000	.2907344 +003	-.3762583 +003
.8000000 +000	.2581977 +003	-.3730931 +003
.7000000 +000	.2258375 +003	-.3718877 +003
.6000000 +000	.1935443 +003	-.3714334 +003
.5000000 +000	.1612762 +003	-.3712644 +003
.4000000 +000	.1290173 +003	-.3712025 +003
.3000000 +000	.9676187 +002	-.3711803 +003
.2000000 +000	.6450760 +002	-.3711726 +003
.1000000 +000	.3225373 +002	-.3711700 +003
.0000000 +000	.0000000 +000	-.3711692 +003

BETA: -1.5

R	H	H DOT
.1500000 +001	.6911504 +003	-.2603693 +004
.1400000 +001	.5327111 +003	-.1249476 +004
.1300000 +001	.4509034 +003	-.7152020 +003
.1200000 +001	.3992794 +003	-.5052539 +003
.1100000 +001	.3594941 +003	-.4231256 +003
.1000000 +001	.3243301 +003	-.3911653 +003
.9000000 +000	.2909600 +003	-.3788030 +003
.8000000 +000	.2582818 +003	-.3740551 +003
.7000000 +000	.2258684 +003	-.3722471 +003
.6000000 +000	.1935554 +003	-.3715656 +003
.5000000 +000	.1612801 +003	-.3713121 +003
.4000000 +000	.1290186 +003	-.3712192 +003
.3000000 +000	.9676228 +002	-.3711859 +003
.2000000 +000	.6450771 +002	-.3711744 +003
.1000000 +000	.3225376 +002	-.3711705 +003
.0000000 +000	.0000000 +000	-.3711693 +003

BETA: -2.0

R	H	H DOT
.1500000 +001	.7602654 +003	-.3347867 +004
.1400000 +001	.5597642 +003	-.1542244 +004
.1300000 +001	.4614386 +003	-.8298797 +003
.1200000 +001	.4033578 +003	-.5499488 +003
.1100000 +001	.3610620 +003	-.4404445 +003
.1000000 +001	.3249279 +003	-.3978308 +003
.9000000 +000	.2911856 +003	-.3813477 +003
.8000000 +000	.2583659 +003	-.3750172 +003
.7000000 +000	.2258992 +003	-.3726065 +003
.6000000 +000	.1935665 +003	-.3716979 +003
.5000000 +000	.1612839 +003	-.3713597 +003
.4000000 +000	.1290199 +003	-.3712360 +003
.3000000 +000	.9676269 +002	-.3711916 +003
.2000000 +000	.6450783 +002	-.3711762 +003
.1000000 +000	.3225378 +002	-.3711710 +003
.0000000 +000	.0000000 +000	-.3711694 +003

UNCLASSIFIED

EXPONENTIAL: APPROACH CURVES AND SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: 2.0

BETA: 2.0

R	H	H DOT
.2000000 +001	.2764602 +003	.3527063 +004
.1900000 +001	.4659600 +003	.1186380 +004
.1800000 +001	.5222176 +003	.2496214 +003
.1700000 +001	.5252018 +003	-.1244160 +003
.1600000 +001	.5069368 +003	-.2733868 +003
.1500000 +001	.4802187 +003	-.3325520 +003
.1400000 +001	.4501477 +003	-.3559765 +003
.1300000 +001	.4187512 +003	-.3652181 +003
.1200000 +001	.3868326 +003	-.3688496 +003
.1100000 +001	.3547092 +003	-.3702702 +003
.1000000 +001	.3225058 +003	-.3708231 +003
.9000000 +000	.2902715 +003	-.3710369 +003
.8000000 +000	.2580251 +003	-.3711190 +003
.7000000 +000	.2257742 +003	-.3711503 +003
.6000000 +000	.1935215 +003	-.3711621 +003
.5000000 +000	.1612682 +003	-.3711665 +003
.4000000 +000	.1290147 +003	-.3711681 +003
.3000000 +000	.9676103 +002	-.3711687 +003
.2000000 +000	.6450736 +002	-.3711689 +003
.1000000 +000	.3225368 +002	-.3711689 +003
.0000000 +000	.0000000 +000	-.3711690 +003

BETA: 1.5

R	H	H DOT
.2000000 +001	.3686135 +003	.2552505 +004
.1900000 +001	.5026750 +003	.7969929 +003
.1800000 +001	.5368048 +003	.9442380 +002
.1700000 +001	.5309795 +003	-.1861042 +003
.1600000 +001	.5092174 +003	-.2978323 +003
.1500000 +001	.4811154 +003	-.3422063 +003
.1400000 +001	.4504987 +003	-.3597746 +003
.1300000 +001	.4188879 +003	-.3667058 +003
.1200000 +001	.3868855 +003	-.3694295 +003
.1100000 +001	.3547295 +003	-.3704949 +003
.1000000 +001	.3225136 +003	-.3709095 +003
.9000000 +000	.2902744 +003	-.3710699 +003
.8000000 +000	.2580262 +003	-.3711315 +003
.7000000 +000	.2257746 +003	-.3711550 +003
.6000000 +000	.1935217 +003	-.3711638 +003
.5000000 +000	.1612683 +003	-.3711671 +003
.4000000 +000	.1290147 +003	-.3711683 +003
.3000000 +000	.9676104 +002	-.3711687 +003
.2000000 +000	.6450736 +002	-.3711689 +003
.1000000 +000	.3225368 +002	-.3711689 +003
.0000000 +000	.0000000 +000	-.3711690 +003

BETA: 1.0

R	H	H DOT
.2000000 +001	.4607669 +003	.1577947 +004
.1900000 +001	.5393900 +003	.4076056 +003
.1800000 +001	.5513920 +003	-.6077378 +002
.1700000 +001	.5367572 +003	-.2477925 +003
.1600000 +001	.5114979 +003	-.3222779 +003
.1500000 +001	.4820120 +003	-.3518605 +003
.1400000 +001	.4508497 +003	-.3635727 +003
.1300000 +001	.4190246 +003	-.3681935 +003
.1200000 +001	.3869384 +003	-.3700093 +003
.1100000 +001	.3547499 +003	-.3707196 +003
.1000000 +001	.3225213 +003	-.3709960 +003
.9000000 +000	.2902773 +003	-.3711029 +003
.8000000 +000	.2580273 +003	-.3711440 +003
.7000000 +000	.2257750 +003	-.3711596 +003
.6000000 +000	.1935218 +003	-.3711655 +003
.5000000 +000	.1612683 +003	-.3711677 +003
.4000000 +000	.1290147 +003	-.3711685 +003
.3000000 +000	.9676104 +002	-.3711688 +003
.2000000 +000	.6450737 +002	-.3711689 +003
.1000000 +000	.3225368 +002	-.3711689 +003
.0000000 +000	.0000000 +000	-.3711690 +003

BETA: .5

R	H	H DOT
.2000000 +001	.5529203 +003	.6033890 +003
.1900000 +001	.5761050 +003	.1821832 +002
.1800000 +001	.5659792 +003	-.2159714 +003
.1700000 +001	.5425349 +003	-.3094807 +003
.1600000 +001	.5137784 +003	-.3467234 +003
.1500000 +001	.4829086 +003	-.3615147 +003
.1400000 +001	.4512006 +003	-.3673708 +003
.1300000 +001	.4191612 +003	-.3696812 +003
.1200000 +001	.3869913 +003	-.3705891 +003
.1100000 +001	.3547702 +003	-.3709443 +003
.1000000 +001	.3225291 +003	-.3710825 +003
.9000000 +000	.2902802 +003	-.3711359 +003
.8000000 +000	.2580284 +003	-.3711565 +003
.7000000 +000	.2257754 +003	-.3711643 +003
.6000000 +000	.1935220 +003	-.3711672 +003
.5000000 +000	.1612684 +003	-.3711683 +003
.4000000 +000	.1290147 +003	-.3711687 +003
.3000000 +000	.9676105 +002	-.3711689 +003
.2000000 +000	.6450737 +002	-.3711689 +003
.1000000 +000	.3225368 +002	-.3711690 +003
.0000000 +000	.0000000 +000	-.3711690 +003

BETA: -.5

R	H	H DOT
.2000000 +001	.7372271 +003	-.1345727 +004
.1900000 +001	.6495350 +003	-.7605562 +003

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.1800000 +001	.5951535 +003	-.5263665 +003
.1700000 +001	.5540904 +003	-.4328572 +003
.1600000 +001	.5183395 +003	-.3956145 +003
.1500000 +001	.4847019 +003	-.3808232 +003
.1400000 +001	.4519025 +003	-.3749671 +003
.1300000 +001	.4194346 +003	-.3726567 +003
.1200000 +001	.3870971 +003	-.3717488 +003
.1100000 +001	.3548109 +003	-.3713936 +003
.1000000 +001	.3225446 +003	-.3712554 +003
.9000000 +000	.2902861 +003	-.3712020 +003
.8000000 +000	.2580306 +003	-.3711814 +003
.7000000 +000	.2257762 +003	-.3711736 +003
.6000000 +000	.1935223 +003	-.3711707 +003
.5000000 +000	.1612685 +003	-.3711696 +003
.4000000 +000	.1290148 +003	-.3711692 +003
.3000000 +000	.9676106 +002	-.3711690 +003
.2000000 +000	.6450737 +002	-.3711690 +003
.1000000 +000	.3225368 +002	-.3711690 +003
.0000000 +000	.0000000 +000	-.3711690 +003

BETA: -1.0

R	H	H DOT
.2000000 +001	.8293805 +003	-.2320285 +004
.1900000 +001	.6862500 +003	-.1149944 +004
.1800000 +001	.6097407 +003	-.6815641 +003
.1700000 +001	.5598681 +003	-.4945454 +003
.1600000 +001	.5206200 +003	-.4200600 +003
.1500000 +001	.4855985 +003	-.3904774 +003
.1400000 +001	.4522535 +003	-.3787652 +003
.1300000 +001	.4195712 +003	-.3741444 +003
.1200000 +001	.3871500 +003	-.3723286 +003
.1100000 +001	.3548312 +003	-.3716183 +003
.1000000 +001	.3225524 +003	-.3713419 +003
.9000000 +000	.2902890 +003	-.3712350 +003
.8000000 +000	.2580317 +003	-.3711939 +003
.7000000 +000	.2257766 +003	-.3711783 +003
.6000000 +000	.1935224 +003	-.3711724 +003
.5000000 +000	.1612685 +003	-.3711702 +003
.4000000 +000	.1290148 +003	-.3711694 +003
.3000000 +000	.9676106 +002	-.3711691 +003
.2000000 +000	.6450737 +002	-.3711690 +003
.1000000 +000	.3225369 +002	-.3711690 +003
.0000000 +000	.0000000 +000	-.3711690 +003

BETA: -1.5

R	H	H DOT
.2000000 +001	.9215338 +003	-.3294843 +004
.1900000 +001	.7229650 +003	-.1539331 +004
.1800000 +001	.6243278 +003	-.8367617 +003
.1700000 +001	.5656458 +003	-.5562337 +003
.1600000 +001	.5229005 +003	-.4445056 +003
.1500000 +001	.4864952 +003	-.4001317 +003
.1400000 +001	.4526045 +003	-.3825633 +003
.1300000 +001	.4197079 +003	-.3756321 +003

.1200000 +001	.3872029 +003	-.3729085 +003
.1100000 +001	.3548516 +003	-.3718430 +003
.1000000 +001	.3225601 +003	-.3714284 +003
.9000000 +000	.2902919 +003	-.3712680 +003
.8000000 +000	.2580328 +003	-.3712064 +003
.7000000 +000	.2257770 +003	-.3711829 +003
.6000000 +000	.1935225 +003	-.3711741 +003
.5000000 +000	.1612686 +003	-.3711708 +003
.4000000 +000	.1290148 +003	-.3711696 +003
.3000000 +000	.9676107 +002	-.3711692 +003
.2000000 +000	.6450737 +002	-.3711690 +003
.1000000 +000	.3225369 +002	-.3711690 +003
.0000000 +000	.0000000 +000	-.3711690 +003

BETA: -2.0

R	H	H DOT
.2000000 +001	.1013687 +004	-.4269401 +004
.1900000 +001	.7596800 +003	-.1928718 +004
.1800000 +001	.6389150 +003	-.9919593 +003
.1700000 +001	.5714235 +003	-.6179219 +003
.1600000 +001	.5251811 +003	-.4689511 +003
.1500000 +001	.4873918 +003	-.4097859 +003
.1400000 +001	.4529554 +003	-.3863614 +003
.1300000 +001	.4198446 +003	-.3771198 +003
.1200000 +001	.3872559 +003	-.3734883 +003
.1100000 +001	.3548719 +003	-.3720677 +003
.1000000 +001	.3225679 +003	-.3715148 +003
.9000000 +000	.2902949 +003	-.3713010 +003
.8000000 +000	.2580338 +003	-.3712189 +003
.7000000 +000	.2257774 +003	-.3711876 +003
.6000000 +000	.1935227 +003	-.3711758 +003
.5000000 +000	.1612686 +003	-.3711714 +003
.4000000 +000	.1290148 +003	-.3711698 +003
.3000000 +000	.9676107 +002	-.3711693 +003
.2000000 +000	.6450738 +002	-.3711691 +003
.1000000 +000	.3225369 +002	-.3711690 +003
.0000000 +000	.0000000 +000	-.3711690 +003

UNCLASSIFIED

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: .5

R SUB I: .353717

BETA: 2.0	R	H	H DOT
	.5000000 +000	.6911504 +002	.0000000 +000
	.4000000 +000	.6911504 +002	.0000000 +000
	.3000000 +000	.6655853 +002	-.2086029 +003
	.2000000 +000	.5146801 +002	-.4618900 +003
	.1000000 +000	.2803156 +002	-.6029421 +003
	.0000000 +000	.0000000 +000	-.6794080 +003

R SUB I: .436399

BETA: 1.5	R	H	H DOT
	.5000000 +000	.9215338 +002	.0000000 +000
	.4000000 +000	.9098342 +002	-.1431962 +003
	.3000000 +000	.7828935 +002	-.4159084 +003
	.2000000 +000	.5653257 +002	-.5708174 +003
	.1000000 +000	.2967146 +002	-.6570841 +003
	.0000000 +000	.0000000 +000	-.7038503 +003

R SUB I: .516338

BETA: 1.0	R	H	H DOT
	.5000000 +000	.1149540 +003	-.6600329 +002
	.4000000 +000	.1050203 +003	-.3643322 +003
	.3000000 +000	.8510703 +002	-.5363896 +003
	.2000000 +000	.5947597 +002	-.6341236 +003
	.1000000 +000	.3062453 +002	-.6885503 +003
	.0000000 +000	.0000000 +000	-.7180556 +003

R SUB I: .594492

BETA: .5	R	H	H DOT
	.5000000 +000	.1314145 +003	-.3063777 +003
	.4000000 +000	.1135481 +003	-.4986783 +003
	.3000000 +000	.8924896 +002	-.6095852 +003
	.2000000 +000	.6126417 +002	-.6725837 +003
	.1000000 +000	.3120354 +002	-.7076668 +003
	.0000000 +000	.0000000 +000	-.7266857 +003

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: 1.0

R SUB I: .594492

BETA: 2.0

R	H	H DOT
.1000000 +001	.1382301 +003	.0000000 +000
.9000000 +000	.1382301 +003	.0000000 +000
.8000000 +000	.1382301 +003	.0000000 +000
.7000000 +000	.1382301 +003	.0000000 +000
.6000000 +000	.1382301 +003	.0000000 +000
.5000000 +000	.1314145 +003	-.3063777 +003
.4000000 +000	.1135481 +003	-.4986783 +003
.3000000 +000	.8924896 +002	-.6095852 +003
.2000000 +000	.6126417 +002	-.6725837 +003
.1000000 +000	.3120354 +002	-.7076668 +003
.0000000 +000	.0000000 +000	-.7266857 +003

R SUB I: .747396

BETA: 1.5

R	H	H DOT
.1000000 +001	.1843068 +003	.0000000 +000
.9000000 +000	.1843068 +003	.0000000 +000
.8000000 +000	.1843068 +003	.0000000 +000
.7000000 +000	.1825120 +003	-.1674510 +003
.6000000 +000	.1695071 +003	-.4100683 +003
.5000000 +000	.1483084 +003	-.5530814 +003
.4000000 +000	.1223005 +003	-.6365618 +003
.3000000 +000	.9349995 +002	-.6847080 +003
.2000000 +000	.6309945 +002	-.7120566 +003
.1000000 +000	.3179780 +002	-.7272867 +003
.0000000 +000	.0000000 +000	-.7355431 +003

R SUB I: .897465

BETA: 1.0

R	H	H DOT
.1000000 +001	.2303835 +003	.0000000 +000
.9000000 +000	.2303835 +003	.0000000 +000
.8000000 +000	.2235456 +003	-.2982909 +003
.7000000 +000	.2062356 +003	-.4826893 +003
.6000000 +000	.1826757 +003	-.5922678 +003
.5000000 +000	.1554150 +003	-.6568599 +003
.4000000 +000	.1259822 +003	-.6945639 +003
.3000000 +000	.9528817 +002	-.7163093 +003
.2000000 +000	.6387148 +002	-.7286613 +003
.1000000 +000	.3204778 +002	-.7355400 +003
.0000000 +000	.0000000 +000	-.7392690 +003

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R SUB I: 1.045783

BETA: .5

R	H	H DØT
.1000000 +001	.2748519 +003	-.1557386 +003
.9000000 +000	.2624906 +003	-.3933390 +003
.8000000 +000	.2420310 +003	-.5363257 +003
.7000000 +000	.2167103 +003	-.6218759 +003
.6000000 +000	.1884900 +003	-.6727140 +003
.5000000 +000	.1585528 +003	-.7026810 +003
.4000000 +000	.1276078 +003	-.7201735 +003
.3000000 +000	.9607772 +002	-.7302621 +003
.2000000 +000	.6421235 +002	-.7359927 +003
.1000000 +000	.3215816 +002	-.7391841 +003
.0000000 +000	.0000000 +000	-.7409141 +003

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: 1.5

R SUB I: .822701

BETA: 2.0

R	H	H DOT
.1500000 +001	.2073451 +003	.0000000 +000
.1400000 +001	.2073451 +003	.0000000 +000
.1300000 +001	.2073451 +003	.0000000 +000
.1200000 +001	.2073451 +003	.0000000 +000
.1100000 +001	.2073451 +003	.0000000 +000
.1000000 +001	.2073451 +003	.0000000 +000
.9000000 +000	.2073451 +003	.0000000 +000
.8000000 +000	.2069217 +003	-.8422545 +002
.7000000 +000	.1968157 +003	-.3575183 +003
.6000000 +000	.1774469 +003	-.5199222 +003
.5000000 +000	.1525932 +003	-.6156528 +003
.4000000 +000	.1245203 +003	-.6715332 +003
.3000000 +000	.9457812 +002	-.7037614 +003
.2000000 +000	.6356493 +002	-.7220681 +003
.1000000 +000	.3194852 +002	-.7322629 +003
.0000000 +000	.0000000 +000	-.7377895 +003

R SUB I: 1.045783

BETA: 1.5

R	H	H DOT
.1500000 +001	.2764602 +003	.0000000 +000
.1400000 +001	.2764602 +003	.0000000 +000
.1300000 +001	.2764602 +003	.0000000 +000
.1200000 +001	.2764602 +003	.0000000 +000
.1100000 +001	.2764602 +003	.0000000 +000
.1000000 +001	.2748519 +003	-.1557386 +003
.9000000 +000	.2624906 +003	-.3933390 +003
.8000000 +000	.2420310 +003	-.5363257 +003
.7000000 +000	.2167103 +003	-.6218759 +003
.6000000 +000	.1884900 +003	-.6727140 +003
.5000000 +000	.1585528 +003	-.7026810 +003
.4000000 +000	.1276078 +003	-.7201735 +003
.3000000 +000	.9607772 +002	-.7302621 +003
.2000000 +000	.6421235 +002	-.7359927 +003
.1000000 +000	.3215816 +002	-.7391841 +003
.0000000 +000	.0000000 +000	-.7409141 +003

R SUB I: 1.266184

BETA: 1.0

R	H	H DOT
.1500000 +001	.3455752 +003	.0000000 +000
.1400000 +001	.3455752 +003	.0000000 +000
.1300000 +001	.3455752 +003	.0000000 +000

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,1200000 +001	,3423895 +003	-,2101449 +003
,1100000 +001	,3282822 +003	-,4217902 +003
,1000000 +001	,3069307 +003	-,5503586 +003
,9000000 +000	,2811874 +003	-,6281193 +003
,8000000 +000	,2527936 +003	-,6749152 +003
,7000000 +000	,2228089 +003	-,7029137 +003
,6000000 +000	,1918752 +003	-,7195517 +003
,5000000 +000	,1603797 +003	-,7293592 +003
,4000000 +000	,1285543 +003	-,7350841 +003
,3000000 +000	,9653742 +002	-,7383858 +003
,2000000 +000	,6441082 +002	-,7402613 +003
,1000000 +000	,3222242 +002	-,7413057 +003
,0000000 +000	,0000000 +000	-,7418719 +003

R SUB I: 1.484985

BETA: ,5

R	H	H DOT
,1500000 +001	,4146902 +003	,0000000 +000
,1400000 +001	,4096659 +003	-,2546220 +003
,1300000 +001	,3941104 +003	-,4458700 +003
,1200000 +001	,3719876 +003	-,5628936 +003
,1100000 +001	,3458525 +003	-,6342559 +003
,1000000 +001	,3172748 +003	-,6776065 +003
,9000000 +000	,2872162 +003	-,7038258 +003
,8000000 +000	,2562640 +003	-,7196044 +003
,7000000 +000	,2247754 +003	-,7290449 +003
,6000000 +000	,1929668 +003	-,7346549 +003
,5000000 +000	,1609688 +003	-,7379617 +003
,4000000 +000	,1288595 +003	-,7398921 +003
,3000000 +000	,9668565 +002	-,7410053 +003
,2000000 +000	,6447481 +002	-,7416377 +003
,1000000 +000	,3224314 +002	-,7419899 +003
,0000000 +000	,0000000 +000	-,7421808 +003

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.038359333
TAU: 6.0
RZERO: 2.0

R SUB I: 1.045783

BETA: 2.0

R	H	H DOT
.2000000 +001	.2764602 +003	.0000000 +000
.1900000 +001	.2764602 +003	.0000000 +000
.1800000 +001	.2764602 +003	.0000000 +000
.1700000 +001	.2764602 +003	.0000000 +000
.1600000 +001	.2764602 +003	.0000000 +000
.1500000 +001	.2764602 +003	.0000000 +000
.1400000 +001	.2764602 +003	.0000000 +000
.1300000 +001	.2764602 +003	.0000000 +000
.1200000 +001	.2764602 +003	.0000000 +000
.1100000 +001	.2764602 +003	.0000000 +000
.1000000 +001	.2748519 +003	-.1557386 +003
.9000000 +000	.2624906 +003	-.3933390 +003
.8000000 +000	.2420310 +003	-.5363257 +003
.7000000 +000	.2167103 +003	-.6218759 +003
.6000000 +000	.1884900 +003	-.6727140 +003
.5000000 +000	.1585528 +003	-.7026810 +003
.4000000 +000	.1276078 +003	-.7201735 +003
.3000000 +000	.9607772 +002	-.7302621 +003
.2000000 +000	.6421235 +002	-.7359927 +003
.1000000 +000	.3215816 +002	-.7391841 +003
.0000000 +000	.0000000 +000	-.7409141 +003

R SUB I: 1.339261

BETA: 1.5

R	H	H DOT
.2000000 +001	.3686135 +003	.0000000 +000
.1900000 +001	.3686135 +003	.0000000 +000
.1800000 +001	.3686135 +003	.0000000 +000
.1700000 +001	.3686135 +003	.0000000 +000
.1600000 +001	.3686135 +003	.0000000 +000
.1500000 +001	.3686135 +003	.0000000 +000
.1400000 +001	.3686135 +003	.0000000 +000
.1300000 +001	.3674509 +003	-.1320763 +003
.1200000 +001	.3560511 +003	-.3729625 +003
.1100000 +001	.3363921 +003	-.5198576 +003
.1000000 +001	.3117052 +003	-.6090921 +003
.9000000 +000	.2839701 +003	-.6630630 +003
.8000000 +000	.2543954 +003	-.6955423 +003
.7000000 +000	.2237166 +003	-.7149750 +003
.6000000 +000	.1923791 +003	-.7265229 +003
.5000000 +000	.1606516 +003	-.7333299 +003
.4000000 +000	.1286952 +003	-.7373033 +003
.3000000 +000	.9660583 +002	-.7395949 +003
.2000000 +000	.6444036 +002	-.7408966 +003
.1000000 +000	.3223199 +002	-.7416215 +003
.0000000 +000	.0000000 +000	-.7420145 +003

R SUB I: 1.630254

BETA: 1.0

R	H	H DOT
.2000000 +001	.4607669 +003	.0000000 +000
.1900000 +001	.4607669 +003	.0000000 +000
.1800000 +001	.4607669 +003	.0000000 +000
.1700000 +001	.4607669 +003	.0000000 +000
.1600000 +001	.4600800 +003	-.1020246 +003
.1500000 +001	.4498193 +003	-.3503307 +003
.1400000 +001	.4310097 +003	-.5031484 +003
.1300000 +001	.4069452 +003	-.5969417 +003
.1200000 +001	.3796600 +003	-.6543334 +003
.1100000 +001	.3504071 +003	-.6893315 +003
.1000000 +001	.3199562 +003	-.7105918 +003
.9000000 +000	.2887791 +003	-.7234505 +003
.8000000 +000	.2571637 +003	-.7311887 +003
.7000000 +000	.2252852 +003	-.7358186 +003
.6000000 +000	.1932498 +003	-.7385699 +003
.5000000 +000	.1611215 +003	-.7401917 +003
.4000000 +000	.1289386 +003	-.7411384 +003
.3000000 +000	.9672407 +002	-.7416844 +003
.2000000 +000	.6449140 +002	-.7419945 +003
.1000000 +000	.3224851 +002	-.7421672 +003
.0000000 +000	.0000000 +000	-.7422608 +003

R SUB I: 1.919803

BETA: .5

R	H	H DOT
.2000000 +001	.5529203 +003	.0000000 +000
.1900000 +001	.5526255 +003	-.6747582 +002
.1800000 +001	.5436362 +003	-.3258165 +003
.1700000 +001	.5257255 +003	-.4858868 +003
.1600000 +001	.5022920 +003	-.5848654 +003
.1500000 +001	.4754471 +003	-.6459315 +003
.1400000 +001	.4464997 +003	-.6835139 +003
.1300000 +001	.4162600 +003	-.7065806 +003
.1200000 +001	.3852282 +003	-.7206949 +003
.1100000 +001	.3537125 +003	-.7293020 +003
.1000000 +001	.3219022 +003	-.7345306 +003
.9000000 +000	.2899133 +003	-.7376929 +003
.8000000 +000	.2578165 +003	-.7395960 +003
.7000000 +000	.2256551 +003	-.7407346 +003
.6000000 +000	.1934551 +003	-.7414112 +003
.5000000 +000	.1612323 +003	-.7418101 +003
.4000000 +000	.1289960 +003	-.7420429 +003
.3000000 +000	.9675196 +002	-.7421772 +003
.2000000 +000	.6450344 +002	-.7422534 +003
.1000000 +000	.3225241 +002	-.7422959 +003
.0000000 +000	.0000000 +000	-.7423189 +003

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: .5

R SUB I: .297246

BETA: 2.0	R	H	H DOT
	.5000000 +000	.6911504 +002	.0000000 +000
	.4000000 +000	.6911504 +002	.0000000 +000
	.3000000 +000	.6911504 +002	.0000000 +000
	.2000000 +000	.5677406 +002	-.2493391 +003
	.1000000 +000	.3063208 +002	-.3362919 +003
	.0000000 +000	.0000000 +000	-.3633429 +003

R SUB I: .373698

BETA: 1.5	R	H	H DOT
	.5000000 +000	.9215338 +002	.0000000 +000
	.4000000 +000	.9215338 +002	.0000000 +000
	.3000000 +000	.8475356 +002	-.2050341 +003
	.2000000 +000	.6115023 +002	-.3182809 +003
	.1000000 +000	.3154972 +002	-.3560283 +003
	.0000000 +000	.0000000 +000	-.3677715 +003

R SUB I: .448733

BETA: 1.0	R	H	H DOT
	.5000000 +000	.1151917 +003	.0000000 +000
	.4000000 +000	.1117728 +003	-.1491455 +003
	.3000000 +000	.9133785 +002	-.2961339 +003
	.2000000 +000	.6299111 +002	-.3472820 +003
	.1000000 +000	.3193574 +002	-.3643307 +003
	.0000000 +000	.0000000 +000	-.3696345 +003

R SUB I: .522891

BETA: .5	R	H	H DOT
	.5000000 +000	.1374259 +003	-.7786933 +002
	.4000000 +000	.1210155 +003	-.2681629 +003
	.3000000 +000	.9424500 +002	-.3363570 +003
	.2000000 +000	.6380391 +002	-.3600868 +003
	.1000000 +000	.3210618 +002	-.3679964 +003
	.0000000 +000	.0000000 +000	-.3704571 +003

UNCLASSIFIED

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: 1.0

R SUB I: .522891

BETA: 2.0

R	H	H DOT
.1000000 +001	.1382301 +003	.0000000 +000
.9000000 +000	.1382301 +003	.0000000 +000
.8000000 +000	.1382301 +003	.0000000 +000
.7000000 +000	.1382301 +003	.0000000 +000
.6000000 +000	.1382301 +003	.0000000 +000
.5000000 +000	.1374259 +003	-.7786933 +002
.4000000 +000	.1210155 +003	-.2681629 +003
.3000000 +000	.9424500 +002	-.3363570 +003
.2000000 +000	.6380391 +002	-.3600868 +003
.1000000 +000	.3210618 +002	-.3679964 +003
.0000000 +000	.0000000 +000	-.3704571 +003

R SUB I: .669630

BETA: 1.5

R	H	H DOT
.1000000 +001	.1843068 +003	.0000000 +000
.9000000 +000	.1843068 +003	.0000000 +000
.8000000 +000	.1843068 +003	.0000000 +000
.7000000 +000	.1843068 +003	.0000000 +000
.6000000 +000	.1780255 +003	-.1864812 +003
.5000000 +000	.1558526 +003	-.3045461 +003
.4000000 +000	.1271977 +003	-.3477712 +003
.3000000 +000	.9618953 +002	-.3632614 +003
.2000000 +000	.6434758 +002	-.3686516 +003
.1000000 +000	.3222018 +002	-.3704483 +003
.0000000 +000	.0000000 +000	-.3710073 +003

R SUB I: .815127

BETA: 1.0

R	H	H DOT
.1000000 +001	.2303835 +003	.0000000 +000
.9000000 +000	.2303835 +003	.0000000 +000
.8000000 +000	.2300400 +003	-.5101229 +002
.7000000 +000	.2155048 +003	-.2515742 +003
.6000000 +000	.1898300 +003	-.3271667 +003
.5000000 +000	.1599781 +003	-.3552959 +003
.4000000 +000	.1285818 +003	-.3655944 +003
.3000000 +000	.9662489 +002	-.3692850 +003
.2000000 +000	.6446930 +002	-.3705692 +003
.1000000 +000	.3224570 +002	-.3709973 +003
.0000000 +000	.0000000 +000	-.3711304 +003

R SUB I: .959902

BETA: .5

R	H	H DOT
.1000000 +001	.2764602 +003	.0000000 +000
.9000000 +000	.2718181 +003	-.1629083 +003
.8000000 +000	.2511460 +003	-.2924327 +003
.7000000 +000	.2232499 +003	-.3417570 +003
.6000000 +000	.1926141 +003	-.3603475 +003
.5000000 +000	.1609511 +003	-.3672653 +003
.4000000 +000	.1289083 +003	-.3697980 +003
.3000000 +000	.9672757 +002	-.3707056 +003
.2000000 +000	.6449801 +002	-.3710215 +003
.1000000 +000	.3225172 +002	-.3711267 +003
.0000000 +000	.0000000 +000	-.3711595 +003

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: 1.5

R SUB I: .742493

BETA: 2.0

R	H	H DOT
.1500000 +001	.2073451 +003	.0000000 +000
.1400000 +001	.2073451 +003	.0000000 +000
.1300000 +001	.2073451 +003	.0000000 +000
.1200000 +001	.2073451 +003	.0000000 +000
.1100000 +001	.2073451 +003	.0000000 +000
.1000000 +001	.2073451 +003	.0000000 +000
.9000000 +000	.2073451 +003	.0000000 +000
.8000000 +000	.2073451 +003	.0000000 +000
.7000000 +000	.2048329 +003	-.1273110 +003
.6000000 +000	.1859938 +003	-.2814468 +003
.5000000 +000	.1586374 +003	-.3388033 +003
.4000000 +000	.1281320 +003	-.3598022 +003
.3000000 +000	.9648341 +002	-.3673274 +003
.2000000 +000	.6442974 +002	-.3699460 +003
.1000000 +000	.3223741 +002	-.3708189 +003
.0000000 +000	.0000000 +000	-.3710904 +003

R SUB I: .959902

BETA: 1.5

R	H	H DOT
.1500000 +001	.2764602 +003	.0000000 +000
.1400000 +001	.2764602 +003	.0000000 +000
.1300000 +001	.2764602 +003	.0000000 +000
.1200000 +001	.2764602 +003	.0000000 +000
.1100000 +001	.2764602 +003	.0000000 +000
.1000000 +001	.2764602 +003	.0000000 +000
.9000000 +000	.2718181 +003	-.1629083 +003
.8000000 +000	.2511460 +003	-.2924327 +003
.7000000 +000	.2232499 +003	-.3417570 +003
.6000000 +000	.1926141 +003	-.3603475 +003
.5000000 +000	.1609511 +003	-.3672653 +003
.4000000 +000	.1289083 +003	-.3697980 +003
.3000000 +000	.9672757 +002	-.3707056 +003
.2000000 +000	.6449801 +002	-.3710215 +003
.1000000 +000	.3225172 +002	-.3711267 +003
.0000000 +000	.0000000 +000	-.3711595 +003

R SUB I: 1.176251

BETA: 1.0

R	H	H DOT
.1500000 +001	.3455752 +003	.0000000 +000
.1400000 +001	.3455752 +003	.0000000 +000
.1300000 +001	.3455752 +003	.0000000 +000

,1200000 +001	,3455752 +003	,0000000 +000
,1100000 +001	,3384915 +003	-,1911273 +003
,1000000 +001	,3163228 +003	-,3018770 +003
,9000000 +000	,2879377 +003	-,3447153 +003
,8000000 +000	,2571551 +003	-,3611677 +003
,7000000 +000	,2254549 +003	-,3674330 +003
,6000000 +000	,1934068 +003	-,3697944 +003
,5000000 +000	,1612281 +003	-,3706731 +003
,4000000 +000	,1290012 +003	-,3709948 +003
,3000000 +000	,9675680 +002	-,3711101 +003
,2000000 +000	,6450618 +002	-,3711502 +003
,1000000 +000	,3225344 +002	-,3711636 +003
,0000000 +000	,0000000 +000	-,3711678 +003

R SUB I: 1.392005

BETA: ,5	R	H	H DØT
	,1500000 +001	,4146902 +003	,0000000 +000
	,1400000 +001	,4146902 +003	,0000000 +000
	,1300000 +001	,4049047 +003	-,2144956 +003
	,1200000 +001	,3814723 +003	-,3101064 +003
	,1100000 +001	,3526485 +003	-,3475078 +003
	,1000000 +001	,3217202 +003	-,3620626 +003
	,9000000 +000	,2899749 +003	-,3676924 +003
	,8000000 +000	,2579146 +003	-,3698546 +003
	,7000000 +000	,2257336 +003	-,3706780 +003
	,6000000 +000	,1935070 +003	-,3709883 +003
	,5000000 +000	,1612631 +003	-,3711038 +003
	,4000000 +000	,1290130 +003	-,3711461 +003
	,3000000 +000	,9676049 +002	-,3711612 +003
	,2000000 +000	,6450721 +002	-,3711665 +003
	,1000000 +000	,3225365 +002	-,3711683 +003
	,0000000 +000	,0000000 +000	-,3711688 +003

EXPONENTIAL: LIMITED SINK RATE APPROACHES AND LIMITED SINK RATE CURVES

RDOT: -.019179667
TAU: 6.0
RZERO: 2.0

R SUB I: .959902

BETA: 2.0

R	H	H DOT
.2000000 +001	.2764602 +003	.0000000 +000
.1900000 +001	.2764602 +003	.0000000 +000
.1800000 +001	.2764602 +003	.0000000 +000
.1700000 +001	.2764602 +003	.0000000 +000
.1600000 +001	.2764602 +003	.0000000 +000
.1500000 +001	.2764602 +003	.0000000 +000
.1400000 +001	.2764602 +003	.0000000 +000
.1300000 +001	.2764602 +003	.0000000 +000
.1200000 +001	.2764602 +003	.0000000 +000
.1100000 +001	.2764602 +003	.0000000 +000
.1000000 +001	.2764602 +003	.0000000 +000
.9000000 +000	.2718181 +003	-.1629083 +003
.8000000 +000	.2511460 +003	-.2924327 +003
.7000000 +000	.2232499 +003	-.3417570 +003
.6000000 +000	.1926141 +003	-.3603475 +003
.5000000 +000	.1609511 +003	-.3672653 +003
.4000000 +000	.1289083 +003	-.3697980 +003
.3000000 +000	.9672757 +002	-.3707056 +003
.2000000 +000	.6449801 +002	-.3710215 +003
.1000000 +000	.3225172 +002	-.3711267 +003
.0000000 +000	.0000000 +000	-.3711595 +003

R SUB I: 1.248221

BETA: 1.5

R	H	H DOT
.2000000 +001	.3686135 +003	.0000000 +000
.1900000 +001	.3686135 +003	.0000000 +000
.1800000 +001	.3686135 +003	.0000000 +000
.1700000 +001	.3686135 +003	.0000000 +000
.1600000 +001	.3686135 +003	.0000000 +000
.1500000 +001	.3686135 +003	.0000000 +000
.1400000 +001	.3686135 +003	.0000000 +000
.1300000 +001	.3686135 +003	.0000000 +000
.1200000 +001	.3655571 +003	-.1356916 +003
.1100000 +001	.3465302 +003	-.2799237 +003
.1000000 +001	.3193875 +003	-.3360517 +003
.9000000 +000	.2890945 +003	-.3577622 +003
.8000000 +000	.2575864 +003	-.3661003 +003
.7000000 +000	.2256132 +003	-.3692756 +003
.6000000 +000	.1934637 +003	-.3704723 +003
.5000000 +000	.1612480 +003	-.3709177 +003
.4000000 +000	.1290079 +003	-.3710807 +003
.3000000 +000	.9675890 +002	-.3711391 +003
.2000000 +000	.6450677 +002	-.3711595 +003
.1000000 +000	.3225356 +002	-.3711662 +003
.0000000 +000	.0000000 +000	-.3711683 +003

R SUB I: 1.535627

BETA: 1.0

R	H	H DOT
.2000000 +001	.4607669 +003	.0000000 +000
.1900000 +001	.4607669 +003	.0000000 +000
.1800000 +001	.4607669 +003	.0000000 +000
.1700000 +001	.4607669 +003	.0000000 +000
.1600000 +001	.4607669 +003	.0000000 +000
.1500000 +001	.4590572 +003	-.1047021 +003
.1400000 +001	.4418647 +003	-.2663371 +003
.1300000 +001	.4155256 +003	-.3301063 +003
.1200000 +001	.3855839 +003	-.3551650 +003
.1100000 +001	.3542291 +003	-.3649676 +003
.1000000 +001	.3223228 +003	-.3687823 +003
.9000000 +000	.2902024 +003	-.3702578 +003
.8000000 +000	.2579994 +003	-.3708245 +003
.7000000 +000	.2257647 +003	-.3710403 +003
.6000000 +000	.1935181 +003	-.3711216 +003
.5000000 +000	.1612670 +003	-.3711519 +003
.4000000 +000	.1290143 +003	-.3711630 +003
.3000000 +000	.9676091 +002	-.3711669 +003
.2000000 +000	.6450733 +002	-.3711683 +003
.1000000 +000	.3225368 +002	-.3711688 +003
.0000000 +000	.0000000 +000	-.3711689 +003

R SUB I: 1.822529

BETA: .5

R	H	H DOT
.2000000 +001	.5529203 +003	.0000000 +000
.1900000 +001	.5529203 +003	.0000000 +000
.1800000 +001	.5522161 +003	-.6954224 +002
.1700000 +001	.5370836 +003	-.2512778 +003
.1600000 +001	.5116267 +003	-.3236590 +003
.1500000 +001	.4820627 +003	-.3524059 +003
.1400000 +001	.4508695 +003	-.3637873 +003
.1300000 +001	.4190323 +003	-.3682776 +003
.1200000 +001	.3869414 +003	-.3700421 +003
.1100000 +001	.3547510 +003	-.3707323 +003
.1000000 +001	.3225218 +003	-.3710009 +003
.9000000 +000	.2902775 +003	-.3711048 +003
.8000000 +000	.2580274 +003	-.3711447 +003
.7000000 +000	.2257750 +003	-.3711599 +003
.6000000 +000	.1935218 +003	-.3711656 +003
.5000000 +000	.1612683 +003	-.3711678 +003
.4000000 +000	.1290147 +003	-.3711685 +003
.3000000 +000	.9676104 +002	-.3711688 +003
.2000000 +000	.6450737 +002	-.3711689 +003
.1000000 +000	.3225368 +002	-.3711689 +003
.0000000 +000	.0000000 +000	-.3711690 +003

Security Classification

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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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U.S. Naval Research Laboratory
Washington, D.C. 20390

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

AIRCRAFT LANDING APPROACH PATHS WITH THE RAINBOW OPTICAL LANDING SYSTEM

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

An interim report on one phase of the problem.

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12. SPONSORING MILITARY ACTIVITY

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13. ABSTRACT

The Rainbow Optical Landing System is designed to present color-sequence-encoded sink-rate-error information to a pilot landing aboard a carrier. As the name implies, the Rainbow system utilizes a tricolor, dynamic light beam projected into the sky from a point near the landing spot.

The approach path and associated sink rate of an aircraft whose pilot is flying the Rainbow system have been determined and plotted for several values of different system parameters. On the basis of these plots, optimal values of beam-pattern parameters can be selected. In addition, the effects on overall system performance of aircraft approach parameters such as initial error, initial range, and rate of approach to the carrier, can be displayed in the form of graphs and numerical tables.

This analytical methodology can be readily applied to other systems which display higher-derivative-command signals.

DD FORM 1 JAN 64 1473

Security Classification

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Landing aids – Color coded						
Landing aids – Optical						
Carrier landings – Equipment						
Projected color display						
Aircraft landings						
Vehicular guidance system						
Rate of descent – Control						
Control system – Quickened						
Error sensitivity – Range independence						

INSTRUCTIONS

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