

AD-A074 146

ARMY MISSILE RESEARCH AND DEVELOPMENT COMMAND REDSTO--ETC F/6 17/7
DEVIATE PROPORTIONAL NAVIGATION.(U)
APR 79 R E DICKSON

UNCLASSIFIED

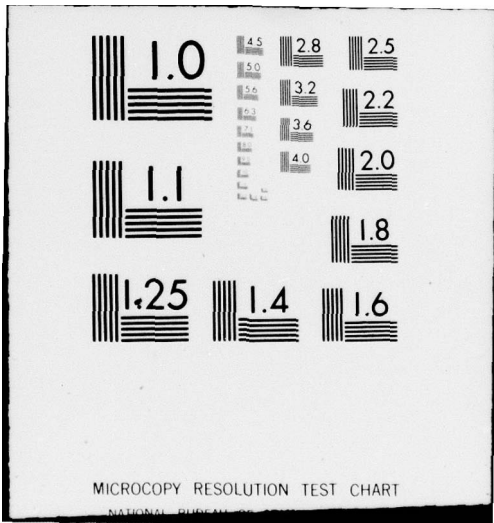
DRDMI-T-79-46

NL

| OF |
ADA
074146



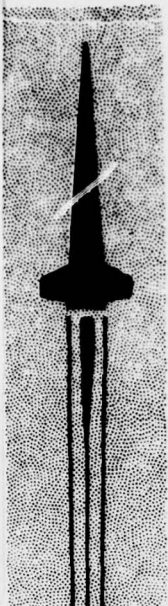
END
DATE
FILMED
10-79
DDC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

ADA 074146



LEVEL

12

DDC
RECEIVED
SEP 24 1979
E

TECHNICAL REPORT T-79-46

**U.S. ARMY
MISSILE
RESEARCH
AND
DEVELOPMENT
COMMAND**

**DEVIATE PROPORTIONAL
NAVIGATION**

Richard E. Dickson
System Simulation Directorate
→ Technology Laboratory
MIRADCOM

9 April 1979

Approved for Public Release;
Distribution Unlimited

Redstone Arsenal, Alabama 35809



DMR FORM 1000, 1 APR 77

79 09 21 009

DDC FILE COPY

DISPOSITION INSTRUCTIONS

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

DISCLAIMER

THE FINDINGS IN THIS REPORT ARE NOT TO BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION UNLESS SO DESIGNATED BY OTHER AUTHORIZED DOCUMENTS.

TRADE NAMES

USE OF TRADE NAMES OR MANUFACTURERS IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL HARDWARE OR SOFTWARE.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TR-79-46	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 DEVIATE PROPORTIONAL NAVIGATION	5. TYPE OF REPORT & PERIOD COVERED 9 Technical Report	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 Richard E./Dickson	8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Commander US Army Missile Research and Development Command ATTN: DRDMI-TD Redstone Arsenal, Alabama 35809	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS Commander US Army Missile Research and Development Command ATTN: DRDMI-TI Redstone Arsenal, Alabama 35809	11. REPORT DATE 9 Apr 1979	12. NUMBER OF PAGES 10
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 13p.	15. SECURITY CLASS. (of this report) Unclassified	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved For Public Release; Distribution Unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
14 DRDMI-T-79-46		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Proportional Navigation Optimal Intercept Attitude Control, Terminal ARM Guidance Optimal Control Anti-Tank Missile Guidance		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A variation of proportional navigation in which the attitude or approach direction at intercept is also controlled is described. Additional sensors are not required but additional on-board computation is required. The derivation is based upon an optimal intercept law.		

DD FORM 1 JAN 79 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

393 427 Luu

ACKNOWLEDGMENT

The author wishes to acknowledge the debt he owes Dr. Vitalij Garber; the collaboration of a decade ago is again bearing fruit.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DDC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or special
A	

CONTENTS

Section	Page
1. Introduction	3
2. Optimal Intercept and Deviate Proportional Navigation	4
3. Conclusions	8

1. INTRODUCTION

"Deviate: To turn aside from a course; to stray, as from a standard."

For decades, proportional navigation has been the standard against which other intercept guidances laws have been compared. For certain applications it is also desirable to control the body attitude at intercept. For example, an anti-tank missile may be more effective against the top of a tank since the sides are designed to withstand kinetic energy rounds. Also, it is desirable to loft the trajectory of anti-radiation missiles (ARM's) to reduce dispersion at impact and to extend the range.

One possible approach would be to incorporate the attitude angle in the state of the system and place cost upon that angle at the terminal time and then optimize, using modern control theory.^{1,2}

The approach in the following is to use an optimal intercept law,^{3,4} and the attitude at intercept is implicit in the choice of the coordinate system. The intercept law was previously found useful in developing an alternative derivation of "lead bias" proportional navigation.⁵

1. M. Kim and K.V. Grider, "Terminal Guidance for Impact Attitude Angle Constrained Flight Trajectories", IEEE AES Vol. 9, No. 6, November 1973, pp. 852-859.
2. R. J. York and H. L. Pastrick, "Optimal Terminal Guidance with Constraints at Final Time", Journal of Spacecraft and Rockets, Vol. 14, No. 6, June 1977, pp. 381-383.
3. A. E. Bryson, Jr., "Linear Feedback Solutions for Minimum Effort Interception, Rendezvous and Soft Landing," AIAA Journal, Vol. 3, No. 8, August 1965, pp. 1542-1544.
4. R.E. Dickson and V. Garber, "Optimum Rendezvous, Intercept and Injection," AIAA Journal, Vol. 7, No. 7, July 1969, pp. 1402-1403.
5. R. E. Dickson, Optimum Intercept Laws and Lead Bias Proportional Navigation (U), US Army Missile Command RD-TR-70-14 (AD-510 828), July 1970 (Confidential).

2. OPTIMAL INTERCEPT AND DEVIATE PROPORTIONAL NAVIGATION

An optimal intercept control law which was previously studied⁴ is

$$u(t) = \frac{-3 x(t_f, t)}{(t_f - t)^2}, \quad (1)$$

where

$$x(t_f, t) = \sum_{n=0}^{\infty} x^{(n)}(t) (t_f - t)^n / n! \quad (2)$$

is the (predicted) miss at the final time, t_f , assuming no (further) control. Only the first two terms of the Taylor series, Equation (2), will be considered here

$$x(t_f, t) \approx x(t) + \dot{x}(t) (t_f - t). \quad (3)$$

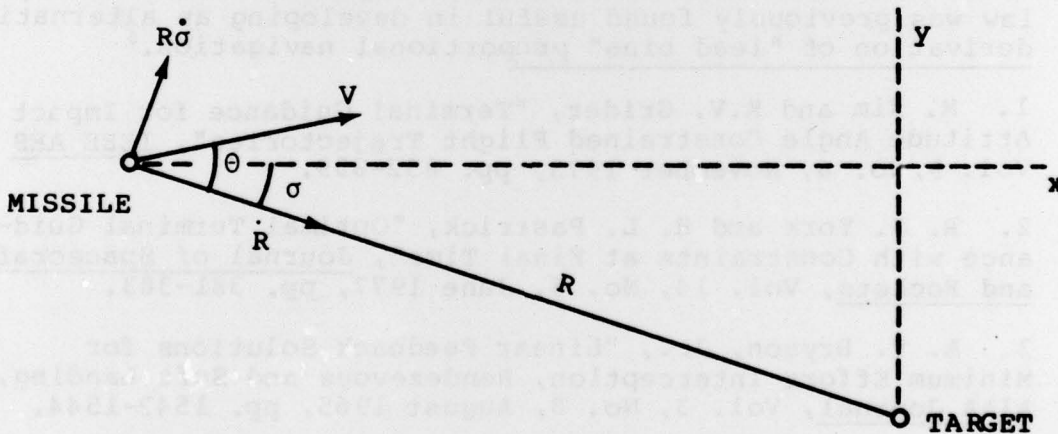


Figure 1. Relative rotating coordinates.

From Figure 1

$$x = -R \cos \sigma \quad (4)$$

$$y = R \sin \sigma \quad (5)$$

$$\dot{x} = \dot{R} \cos \sigma + R \dot{\sigma} \sin \sigma \quad (6)$$

$$\dot{y} = R \dot{\sigma} \cos \sigma - \dot{R} \sin \sigma. \quad (7)$$

It follows from Equation (3) that

$$x(t_f, t) \approx -R \cos \sigma + (\dot{R} \cos \sigma + R \dot{\sigma} \sin \sigma) (t_f - t) \quad (8)$$

and

$$y(t_f, t) \approx R \sin \sigma + (R \dot{\sigma} \cos \sigma - \dot{R} \sin \sigma) (t_f - t) \quad (9)$$

Setting

$$x(t_f, t) = 0, \quad (10)$$

it follows that the time to go is

$$(t_f - t) \approx \frac{R \cos \sigma}{\dot{R} \cos \sigma + R \dot{\sigma} \sin \sigma} \quad (11)$$

Then the control $u(t)$, is along the y-axis,

$$u(t) = \frac{-3y(t_f, t)}{(t_f - t)^2} \quad (12)$$

$$\approx -3 \left\{ \frac{y(t) + \dot{y}(t) (t_f - t)}{(t_f - t)^2} \right\} \quad (13)$$

$$\approx -3 \left[\frac{R \sin \sigma}{\dot{R} \cos \sigma + R \dot{\sigma} \sin \sigma} \right]^2 + \frac{R \dot{\sigma} \cos \sigma - \dot{R} \sin \sigma}{\dot{R} \cos \sigma + R \dot{\sigma} \sin \sigma} \quad (14)$$

and, after some manipulation,

$$\approx -3 (\dot{R} + R \dot{\sigma} \tan \sigma) \dot{\sigma} / \cos \sigma, \quad (15)$$

or, factoring out an \dot{R} ,

$$\approx -3 \dot{R} \dot{\sigma} (1 + \tan \theta \tan \sigma) / \cos \sigma, \quad (16)$$

Near a collision course, small angles may be neglected and Equation (16) may be simplified to

$$u(t) \approx -3 \dot{R} \dot{\sigma}, \quad (17)$$

proportional navigation!

Retaining small angles, Equation (15) becomes

$$u(t) \approx -3(\dot{R} \dot{\sigma} + R \dot{\sigma}^2 \sigma), \quad (18)$$

and Equation (16) becomes

$$u(t) \approx -3(1 + \theta \cdot \sigma) \dot{R} \dot{\sigma}, \quad (19)$$

or

$$u(t) \approx -3 \left[1 + \left(\frac{R}{\dot{R}} \right) \dot{\sigma} \sigma \right] \dot{R} \dot{\sigma}. \quad (20)$$

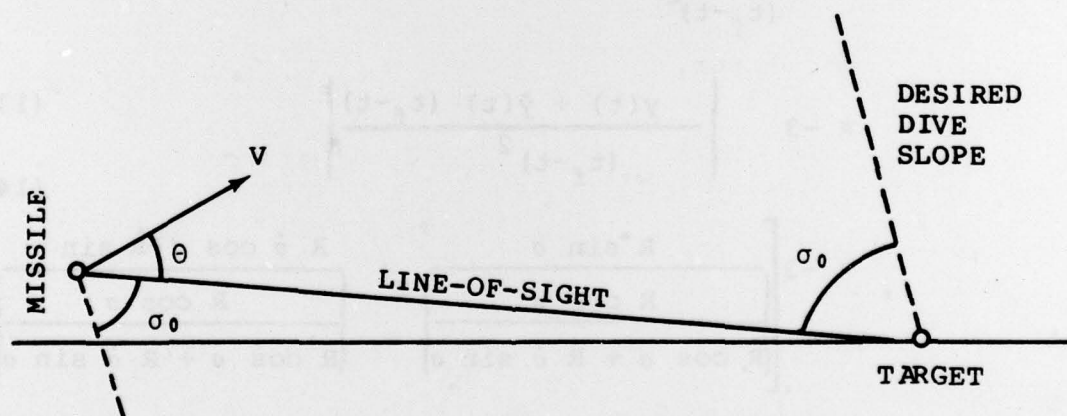


Figure 2. Deviate proportional navigation.

In Figure 2, the line-of-sight (LOS) angle, σ , is chosen initially to be negative; the dive slope is the x-axis. The effect of a negative line-of-sight angle, σ_0 , and positive theta, θ , in Equations (18), (19) and (20) is to reduce the "gain" until the missile is in the vicinity of the desired

diverge slope. The line-of-sight angle, σ , is usually referenced to the horizontal as in Figure 1, but this is not necessary nor may it be desirable when the effects of the small angles, θ and σ , are included.

Measurement of the relative range, R , is generally not practical and Equation (18) will be eliminated from further consideration. The addition of an angle of attack sensor would allow determination of theta, θ , assuming that the effects of the velocity of the target and the winds are insignificant, but this sensor could interfere with the LOS rate, $\dot{\sigma}$, sensor.

This leaves Equation (20). The signal received by the LOS rate sensor is proportional to the range,

$$e = \frac{J}{R^n} \quad (21)$$

Taking the log of both sides of Equation (21),

$$\ln e = \ln J - n \ln R \quad (22)$$

and then differentiating,

$$\frac{\dot{e}}{e} = \frac{\dot{J}}{J} - n \left(\frac{\dot{R}}{R} \right) \quad (23)$$

Assuming that

$$\dot{J} = 0, \quad (24)$$

$$\frac{\dot{R}}{R} = -n \left(\frac{\dot{e}}{e} \right), \quad (25)$$

as required in Equation (20). For a point source an inverse square law would be appropriate, i.e.,

$$n = 2. \quad (26)$$

Under these assumptions and assuming that the closing rate, R , is known approximately, no additional sensors are needed but additional on-board computation is required (see Figure 3).

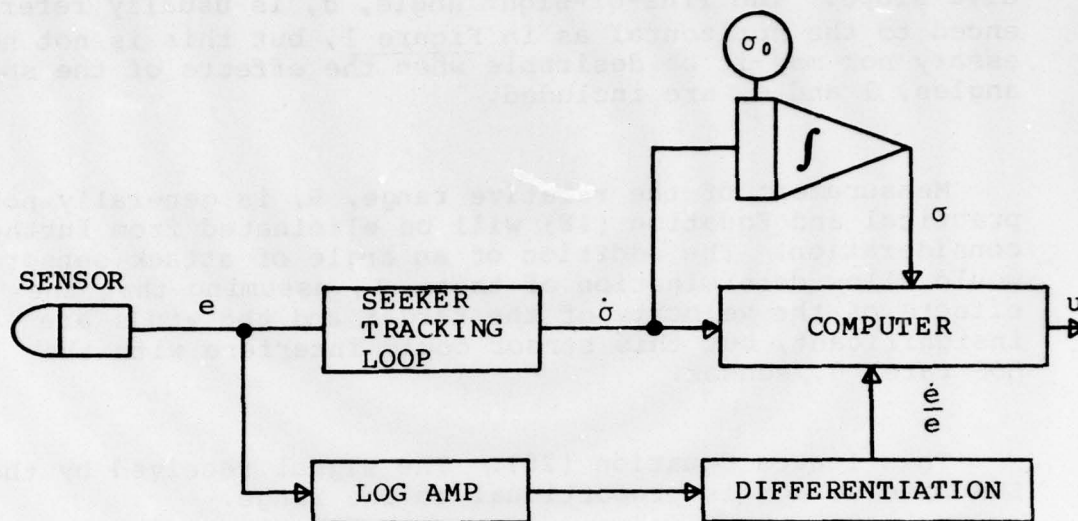


Figure 3. DPN implementation.

Of course, the launch condition, θ , and the initial condition on the integrator, σ_0 , must be chosen so as to achieve the desired dive slope at intercept.

It would seem that the initial condition on the integrator, σ_0 , could have a fixed value and that theta, θ , would be tailored to the launch conditions of the particular flight, i.e., the range and altitude at launch.

Implementation might be further simplified by assuming that (R/R) is Equation (20) is a constant.

3. CONCLUSIONS

Since deviate proportional navigation (DPN) reduces to proportional navigation (PN) in the vicinity of the desired dive slope, there would be no advantage in implementing Equations (15) or (16).

The assumptions which were made would not appear critical in the "end game". With microelectronics the additional "on-board" computation required does not appear to be the problem it would have been in the past.

Since the purpose of this report is to close the loop, feedback is welcomed. The name "devious" proportional navigation has already been suggested.

DISTRIBUTION

	No. of Copies
Defense Documentation Center Cameron Station Alexandria, Virginia 22314	12
Dr. Vitalij Garber Director, International Programs Pentagon E 3-1082 Washington, D. C. 20301	1
IIT Research Institute Attn: GACIAC 10 West 35th St. Chicago, Illinois 60616	1
US Army Material Systems Analysis Activity Attn: DRXSY-MP Aberdeen Proving Ground, Maryland 21005	1
DRSMI-LP, Mr. Voigt	1
DRDMI-T, Dr. Kobler	1
DRDMI-TN, W. Leonard	1
DRDMI-TBD	3
DRDMI-TI (Reference Copy)	1
DRDMI-TI (Record Set)	1
DRDMI-TD, Dr. McCorkle	1
DRDMI-TD, Dr. Grider	1
DRDMI-TDD, R. Powell	1
DRDMI-TDD, D. Holder	1
DRDMI-TDD, J. Gibbons	1
DRDMI-TDF, R. Davis	1
DRDMI-TDF, V. Grimes	1
DRDMI-TDK, Dr. Jenkins	1
DRDMI-TDW, H. Dihm	1
DRDMI-TDW, A. Jolly	1
DRDMI-TDW, J. L. Harris	1
DRDMI-TDW, R. Dickson	10
DRDMI-TE	1
DRDMI-TG	1

DISTRIBUTION

	No. of Copies
DRDMI-TGN, R. Gambill	1
DRDMI-TGN, Dr. Pastrick	1
DRDMI-TGN, C. Lewis	5
DRDMI-TGT, W. Jordan	1
DRDMI-TGT, Dr. Jacobs	1
DRDMI-TGT, E. Evers	1
DRDMI-TR	1
DRDMI-Y	1
DRDMI-Z	1
DRCPM-LDE	1
DRDMI-MPE	1

