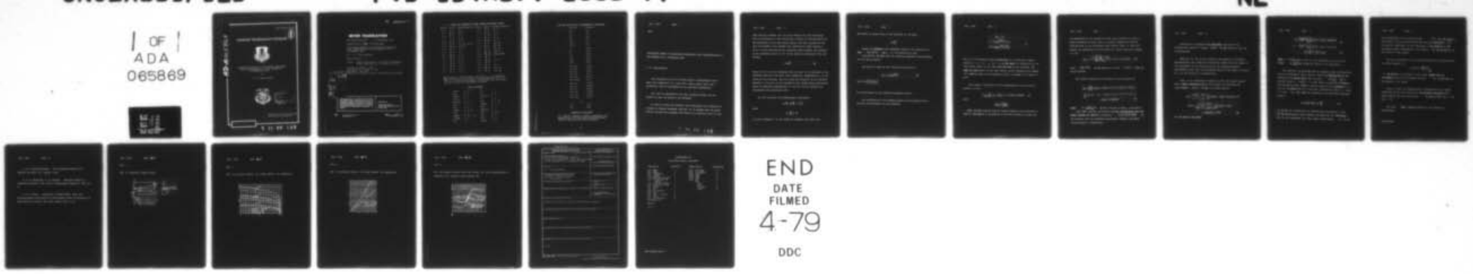
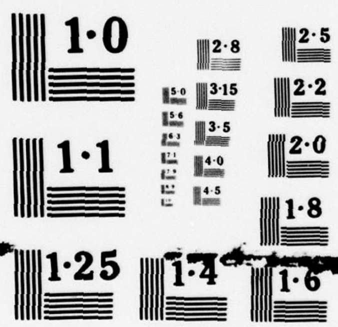
AD-A065 869 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 20/4
APPROXIMATE METHOD OF CALCULATING AERODYNAMIC WING CHARACTERIST--ETC(U)
SEP 77 V A GRAYVORONSKIY
UNCLASSIFIED FTD-ID(RS)T-1636-77 NL

1 OF 1
ADA
065869



END
DATE
FILMED
4-79
DDC


1·0
2·8
2·5
5·0
3·15
2·2
5·6
6·3
3·5
1·1
2·0
4·0
4·5
1·8
1·25
1·4
1·6

FTD-ID(RS)T-1636-77

FOREIGN TECHNOLOGY DIVISION

APPROXIMATE METHOD OF CALCULATING AERODYNAMIC WING CHARACTERISTICS IN THE PRESENCE OF A CYLINDRICAL BODY

by

V. A. Grayvoronskiy

8 11 09 143

EDITED TRANSLATION

FTD-ID(RS)T-1636-77 14 September 1977

MICROFICHE NR: FTD-77-C-001165

APPROXIMATE METHOD OF CALCULATING AERODYNAMIC WING CHARACTERISTICS IN THE PRESENCE OF A CYLINDRICAL BODY

By: V. A. Grayvoronskiy

English pages: 13

Source: Samoletostroyeniye i Tekhnika Vozdushnogo Flota, Khar'kov, No. 23, 1970, PP. 3-8

Country of origin: USSR
Translated by: Carol S. Nack
Requester: FTD/PDRS
Approved for public release; distribution unlimited

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	Α	α	ɑ	Nu	Ν	ν	
Beta	Β	β		Xi	Ξ	ξ	
Gamma	Γ	γ		Omicron	Ο	ο	
Delta	Δ	δ		Pi	Π	π	
Epsilon	Ε	ε	ϵ	Rho	Ρ	ρ	ϱ
Zeta	Ζ	ζ		Sigma	Σ	σ	ς
Eta	Η	η		Tau	Τ	τ	
Theta	Θ	θ	ϑ	Upsilon	Τ	υ	
Iota	Ι	ι		Phi	Φ	φ	ϕ
Kappa	Κ	ϰ κ	ϰ	Chi	Χ	χ	
Lambda	Λ	λ		Psi	Ψ	ψ	
Mu	Μ	μ		Omega	Ω	ω	

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	sin^{-1}
arc cos	cos^{-1}
arc tg	tan^{-1}
arc ctg	cot^{-1}
arc sec	sec^{-1}
arc cosec	csc^{-1}
arc sh	$sinh^{-1}$
arc ch	$cosh^{-1}$
arc th	$tanh^{-1}$
arc cth	$coth^{-1}$
arc sch	$sech^{-1}$
arc csch	$csch^{-1}$

---

rot	curl
lg	log

GRAPHICS DISCLAIMER

All figures, graphics, tables, *equations*, etc. merged into this translation were extracted from the best quality copy available.

1636

APPROXIMATE METHOD OF CALCULATING AERODYNAMIC WING CHARACTERISTICS IN THE PRESENCE OF A CYLINDRICAL BODY

V. A. Grayvoronskiy

The continuous flow of a steady perfect incompressible fluid about the combination of a wing with a small aspect ratio and a cylindrical body is considered in the nonlinear formulation.

The wing is considered to be thin, slightly curved, and its surface is near the plane of the meridian.

In order to solve the problem, wing cantilevers are simulated by a system of oblique horseshoe vortices. It is assumed that the bound lifting vortices are arranged like those of an isolated wing [1]. The

8 11 09 143

free vortices converge with the wing surface [2]. The cylindrical body is replaced by a flat dipole and a system of vortices which are the reflection of the wing vortex system. The free vortices of the wing are assumed to be stepped with sufficiently small spacing t (Fig. 1) when constructing the reflected vortex system. The position of the reflected points of the vortex system is determined from the formula

$$r^{*}=\frac{a^{2}}{r}, \quad (1)$$

where r* and r are the distances from the axis of the cylinder to the reflected point and the point being reflected, respectively; a is the radius of the cylinder. Here the value and direction of the sections parallel to the axis of the cylinder do not change during reflection, while the sections perpendicular to the axis of the cylinder are transformed into peripheral arcs.

We will introduce the dimensionless coordinates

$$\xi=\frac{x_1}{\delta};\ \eta=\frac{y_1}{\delta};\quad \zeta=\frac{z_1}{\delta},$$

where

$$\delta=\frac{L}{4n}(1-\sigma);$$

L is the wingspan; n is the number of elements into which the cantilever is broken down in the direction of the span;

$$\sigma = \frac{2a}{L}.$$

Using ν to designate the horseshoe vortex in the direction of axis $O\zeta$ $(1 \leq \nu \leq n)$ and μ - in the direction of axis $O\xi$ $(1 \leq \mu \leq m)$, we will have the following geometric relationships for the vortex system.

The angle of sweep of the reflected bound vortex -

$$\chi^*_{\nu\mu} = -\operatorname{arc\,tg}\left(\frac{\operatorname{tg}\chi_\mu}{\delta^*_\nu}\right), \qquad (2)$$

where $\delta^*_\nu = \frac{a^2}{2}\left(\frac{\zeta_\nu - \zeta_{\nu-1}}{\zeta_\nu \cdot \zeta_{\nu-1}}\right)$

is the half-span of the reflected horseshoe vortex.

The coordinates of the breaking points of the reflected free vortices are determined by the formulae:

$$\xi^{*}_{\nu\mu(s)} = \xi_{\nu\mu(s)};$$
$$\eta^{*}_{\nu\mu(s)} = \frac{a^2 st \operatorname{tg} \gamma_{\nu\mu}}{(st \operatorname{tg} \gamma_{\nu\mu})^2 + (a+2\nu)^2};$$
$$\zeta^{*}_{\nu\mu(s)} = \frac{a^2 (a+2\nu)}{(st \operatorname{tg} \gamma_{\nu\mu})^2 + (a+2\nu)^2}; \quad (3)$$

Here s is the sequence numbe of the stage of an arbitrary stepped vortex (s = 0, 1, 2, ..., N); $\gamma_{\nu\mu}$ is the angle of inclination of the free vortex, which is far away from the axis of the cylinder. The angle of inclination of the free vortex, which converges with element $\nu=1$ and is close to the cylinder's axis, is assumed to be equal to zero.

The boundary conditions of the inpenetrability of the wing at points j, q are:

$$1 + \frac{a^2}{(a+2j-1)^2} + (V^{*}_{\eta\Sigma})_{jq} = 0 \quad (1 < j \leqslant n,\ 1 < q \leq m), \quad (4)$$

where

$$(V^{*}_{\eta\Sigma})_{jq} = \frac{(V_{\eta\Sigma})_{jq}}{V_{\infty} \sin a};$$

$(V_{\eta\Sigma})_{jq}$ is the velocity from the vortex system in the direction of axis $o\eta$. The angles of incination of the free vortices to plane $\xi o \zeta$

are determined by the direction of the local velocity at point F, whose projection on plane $\xi o \zeta$ is a certain distance Δb from the trailing edge of the cantilever cross section (Fig. 1). Here the formula for determining the direction of a free vortex with numbers i, p is

$$\operatorname{tg} \gamma_{ip} = \frac{1 + a^2 \dfrac{\zeta_i^2 - \eta_{ip}^2}{(\zeta_i^2 + \eta_{ip}^2)^2} + (V^*_{\eta\Sigma})_{ip}}{\operatorname{ctg} \alpha + (V^*_{\xi\Sigma})_{ip}} \quad (1 \leq i \leq n,\ 1 \leq p \leq m). \tag{5}$$

where $(V^*_{\xi\Sigma})_{ip}$, $(V^*_{\eta\Sigma})_{ip}$ is the velocity at point $(\xi_{ip}, \eta_{ip}, \zeta_i)$ from the vortex systems.

The velocity operator in direction k can be written as:

$$(V^*_{k\Sigma})_0 = \sum_{f=1}^{2} \sum_{\mu=1}^{m} \{ \Gamma^*_{\nu\mu} [(V_k)_0^{f\nu\mu} + (W_k)_0^{f\mu\nu} + (V^*_{\text{г.к}})_0^{f\nu\mu s} + (V^*_{\text{в.к}})_0^{f\nu\mu s} + (W^*_k)_0^{f\mu\nu}]_{\nu=1} +$$
$$+ \sum_{\nu=2}^{n} \Gamma^*_{\nu\mu} [(V_k)_0^{f\nu\mu} - (V_k)_0^{f\nu-1\mu} + (W_k)_0^{f\mu\nu} + (V^*_{\text{г.к}})_0^{f\nu\mu s} + (V^*_{\text{в.к}})_0^{f\nu\mu s} - (V^*_{\text{г.к}})_0^{f\nu-1\mu s} -$$
$$- (V^*_{\text{в.к}})_0^{f\nu-1\mu s} + (W^*_k)_0^{f\mu\nu}] \}. \tag{6}$$

where $\Gamma^*_{\nu\mu} = \dfrac{\Gamma_{\nu\mu}}{4\pi\delta V_\infty \sin\alpha}$; $\Gamma_{\nu\mu}$ is the intensity of the ν, μ-th vortex;

$(V_k)_0^{f\nu\mu}$, $(W_k)_0^{f\mu\nu}$ are the velocities from the corresponding free and bound vortices of identical intensity; $(V^*_{\text{г.к}})_0^{f\nu\mu s}$, $(V^*_{\text{в.к}})_0^{f\nu\mu s}$, $(W^*_k)_0^{f\mu\nu}$ is the velocity from the reflected horizontal, vertical, and bound vortex segments, respectively.

Coefficient f determines the cantilever. In view of the insignificant effect of values $(V^{*}_{yk})^{fus}_{0}$ on the solution, they can be disregarded.

Equations (4) and (5) are solved by the method of successive approximations. The numerical calculations showed that the nature of the convergence of the solution due to the iteration process corresponds to the case of an isolated wing [2]. The effect of values Δb, t on the solution is insignificant.

Using N. Ye. Zhukovskiy's theorem on lift "on a small scale," after simple transformations we will obtain the following for coefficients c_n and c_m in the j-th cross section:

$$(c_n)_j=\frac{2\pi\lambda_k\left(\frac{1}{\eta_k}+1\right)\sin^2\alpha}{n-\left(1-\frac{1}{\eta_k}\right)(2j-1)}\sum_{p=1}^{m}\Gamma^{*}_{jp}[\mathrm{ctg}\,\alpha+(V^{*}_{iz})_{jp}-(V^{*}_{iz})_{jp}\,\mathrm{tg}\,\chi_p]; \quad (7)$$

$$(c_m)_j=-\frac{2\pi\lambda_k\left(\frac{1}{\eta_k}+1\right)\sin^2\alpha}{m\left[2n-\left(1-\frac{1}{\eta_k}\right)(2j-1)\right]}\sum_{p=1}^{m}\Gamma^{*}_{jp}[\mathrm{ctg}\,\alpha+(V^{*}_{iz})_{jp}-$$

$$-(V^{*}_{iz})_{jp}\,\mathrm{tg}\,\chi_p]\,(p-0{,}75). \quad (8)$$

For the wing on the whole

$$c_n = \frac{2\pi\lambda_k \sin^2\alpha}{n^2} \sum_{j=1}^{n} \sum_{p=1}^{m} \Gamma^*_{jp} [\mathrm{ctg}\,\alpha + (V^*_{\xi\Sigma})_{jp} - (V^*_{\zeta\Sigma})_{jp}\,\mathrm{tg}\,\chi_p]; \tag{9}$$

$$m_z = -\frac{2\pi\lambda_k \sin^2\alpha}{n^2} \sum_{j=1}^{n} \sum_{p=1}^{m} \Gamma^*_{jp} [\mathrm{ctg}\,\alpha + (V^*_{\xi\Sigma})_{jp} - (V^*_{\zeta\Sigma})_{jp}\,\mathrm{tg}\,\chi_p] \times \left(\frac{p-0{,}75}{m} + \frac{2j-1}{b_1}\,\mathrm{tg}\,\chi_p\right). \tag{10}$$

where $\lambda_к$ is the aspect ratio of the cantilever; b_1 is the root chord; $\eta_к = \frac{b_1}{b_{конц}}$ ($b_{конц}$ is the tip chord of the cantilever).

The numerical calculations made by computer agree satisfactorily with the experimental data. Figure 2 shows the distribution of the coefficient of normal force over the span - $\bar{z} = 2\frac{\;\;-a}{L-2a}$ for a straight wing ($\lambda_к$ = 2.00, σ = 0.185) which is centrally located on the cylindrical body. Figure 3 shows a graph of the dependence c_y = f(α) of the combination of a wing and a cylindrical body ($\lambda_к$ = 0.61, σ = 0.39, $\lambda_{н.т}$ = 10). The lift coefficient was determined from the formula

$$c_y = c_{yк}(k_a + \Delta k_a) + c_{yн.т}\frac{S_м}{S_к}. \tag{11}$$

$c_{yк}$ is the lift coefficient of isolated wing cantilevers; k_a, Δk_a are the coefficients which consider the effect of the cylindrical body on the cantilever, and vice versa, respectively; $c_{yн.т}$ is the lift coefficient of the isolated body; $S_м$, $S_к$ are the areas of the middle of the cylindrical body and the wing cantilever; $c_{yк} \cdot k_к$ is the lift coefficient of the cantilever in the presence of the cylindrical body, determined by this method. $\Delta k_к$ was determined by the theory of thin bodies.

The lift coefficient of an isolated housing was calculated from the Allen formula [3]:

$$c_{y.цт} = 2\alpha + c_{xц.} \frac{S_{план}}{S_м} \sin^2 \alpha, \tag{12}$$

$c_{xц.}$ was assumed to be equal to 0.35, which agreed with the experimental data for an isolated housing; $S_{план}$ is the area of the housing in the plane.

Figure 4 shows the characteristic distribution of the normal velocities in the cross section of the cylinder calculated for a vortex system with one free vortex $(\Gamma^* \sin\alpha = 1;\ \sigma = 0{,}5)$ at γ = 15° and γ = 0°.

The value $(V_{iз}^{*})_{jp}$ was disregarded in the theoretical calculations.

Bibliography

1. S. M. Belotserkovskiy. Thin Supporting Surface in a Subsonic Gas Flow. Izd. "Nauka," 1965.

2. S. D. Yermolenko, A. V. Rovnykh. Nonlinear Theory of Supporting Surfaces. "Izd. Vuzov, Aviatsionnaya tekhnika," 1967, No. 2.

3. H. R. Kelly. Estimation of Normal-Force, Drag, and Pitching-Moment Coefficients for Blunt-Based Solids of Revolution at Large Angles of Attack, IAS, VIII, August 1954, V. 21.

Fig. 1.

KEY: (1) Arbitrary stepped vortex.

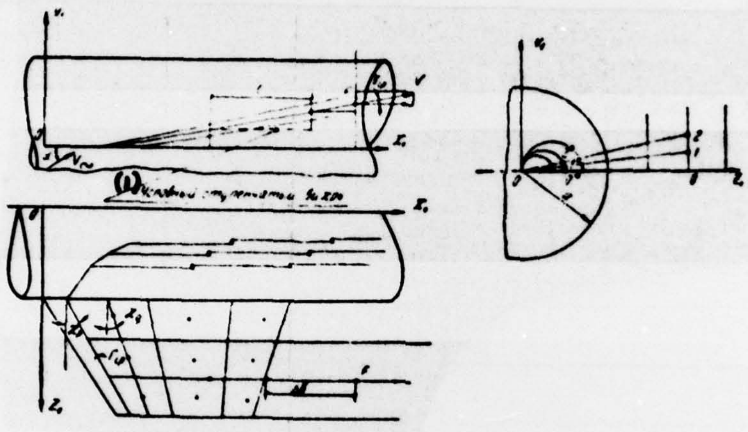


Fig. 2.

KEY: (1) Nonlinear method. (2) Linear method. (3) Experiment.

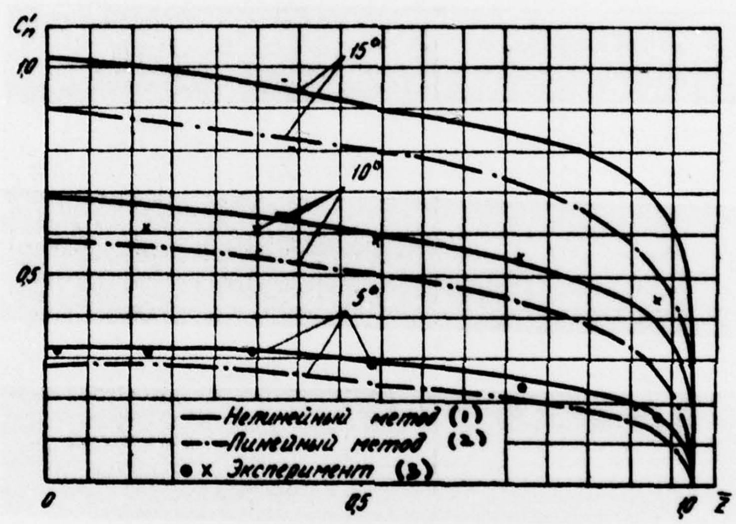


Fig. 3.

KEY: (1) Nonlinear method. (2) Linear method. (3) Experiment.

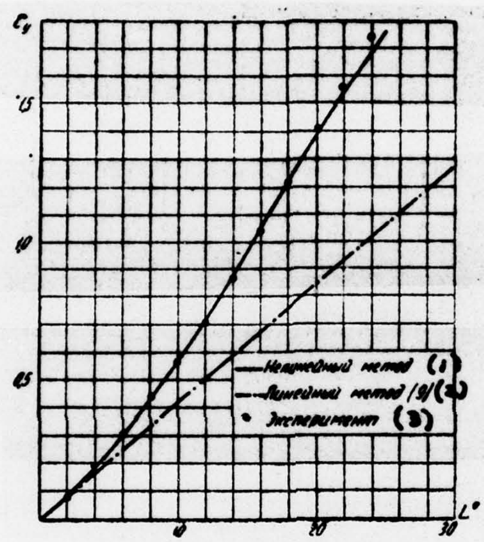
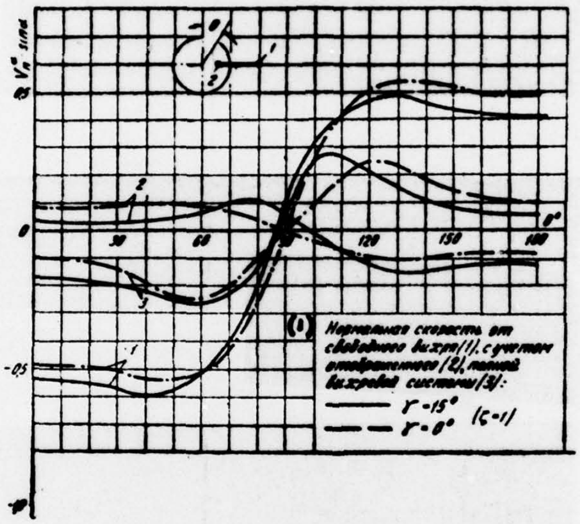


Fig. 4.

KEY: (1) Normal velocity from free vortex (1), with consideration of reflected (2), complete vortex system (3).



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER FTD-ID(RS)T-1636-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) APPROXIMATE METHOD OF CALCULATING AERODYNAMIC WING CHARACTERISTICS IN THE PRESENCE OF A CYLINDRICAL BODY		5. TYPE OF REPORT & PERIOD COVERED Translation
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) V. A. Grayvoronskiy		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Foreign Technology Division Air Force Systems Command U. S. Air Force		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1970
		13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		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)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) 01;20		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE
A205	DMATC	1
A210	DMAAC	2
B344	DIA/RDS-3C	8
C043	USAMIIA	1
C509	BALLISTIC RES LABS	1
C510	AIR MOBILITY R&D LAB/FIO	1
C513	PICATINNY ARSENAL	1
C535	AVIATION SYS COMD	1
C557	USAIIC	1
C591	FSTC	5
C619	MIA REDSTONE	1
D008	NISC	1
H300	USAICE (USAREUR)	1
P005	ERDA	1
P055	CIA/CRS/ADD/SD	1
NAVORDSTA (50L)		1
NASA/KSI		1
AFIT/LD		1

ORGANIZATION		MICROFICHE
E053	AF/INAKA	1
E017	AF/ RDXTR-W	1
E404	AEDC	1
E408	AFWL	1
E410	ADTC	1
E413	ESD	2
	FTD	
	CCN	1
	ETID	3
	NIA/PHS	1
	NICD	5