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Technical Memorandum

SC-TM-69-847
December 1969

SANDIA SYSTEMATIC DECLASSIFICATION REVIEW	
1st Review Date: 1-11-96 Authority: ☐ADC ☒ADD W. Lange Name: 2nd Review Date: 1-16-96 Authority: ADD Name: K. D. Smith	Determination (Circle Numbers): 1. Classification Retained 2. Classification Changed to: U 3. Contains No DOE Classified Information 4. Coordinate With: 5. Contains UCNI? 6. Comments:

A NEW FLIGHT FORMATION (U)

Alan Pope, 9300
Sandia Laboratories, Albuquerque

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SANDIA SYSTEMATIC DECLASSIFICATION REVIEW DOWNGRADING OR DECLASSIFICATION STAMP	
CLASSIFICATION CHANGED TO: U Emelda Sleph 05/23/96 PERSON CHANGING MARKING & DATE R.L. 6/19/86 PERSON VERIFYING MARKING & DATE	AUTHORITY: ~~96SN012~~ K. D. Smith RECORD ID: 96SN012 DATED: 01-16-96

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OPERATED FOR THE UNITED STATES ATOMIC ENERGY COMMISSION BY SANDIA CORPORATION | ALBUQUERQUE, NEW MEXICO, LIVERMORE, CALIFORNIA

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A NEW FLIGHT FORMATION (U)

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ABSTRACT (~~CDI~~)

A rough order of magnitude study of the F-111 airplane and its capabilities in the area of low level flight indicates that very low level (about 100-foot altitude) supersonic sweeps can produce disorganizing damage, particularly in cities (broken windows, minor dwelling damage). Three F-111's in a wing tip-to-wing tip formation can (in a similar flight) increase the damage level to moderate (some eardrums broken, damage to parked aircraft, and radar vans).

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SUMMARY

A theory developed and corroborated by NASA during the sonic boom program and the low altitude performance of the F-111 have been combined to estimate the maximum shock pulse put on the ground by a flight of three F-111 fighters at low altitude in a wing tip-to-wing tip configuration, flying at M = 1.2.

The values of overpressure which seem possible are as follows:

Altitude (ft)	Δp_{max} (psi)
75	6.8
150	3.8
225	3.0
300	2.4

Arguments are given that the duration of the above pressures correspond to that from a 1-kt nuclear blast. Accordingly they will:

(a) Break out all windows,

(b) Break some eardrums,

(c) Probably trigger some personnel mines,

(d) Damage parked aircraft,

(e) Probably damage radar vans, and

(f) Knock down weak dwellings.

The author suggests both a consideration of very low formation flights and a reconsideration of the damage a single plane can do.

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A NEW FLIGHT FORMATION

Introduction

The availability of the terrain avoidance low level auto-pilot in the F-111 makes it practical to fly at low heights--of the order of 100 feet--at high speed and at night. At these low heights the shock wave generated by a single plane is enough to break windows, knock down fluorescent lights and insulation panels, make dust clouds, damage parked aircraft, and in general make quite an irritating environment, without personnel damage beyond cuts from flying glass.

The lateral spread of pressure is such that the maximum overpressure (which occurs directly along the aircraft flight line) falls off to one-half the maximum laterally out a distance equal to the altitude. This slow fall-off is such that it appears reasonable to consider a wing tip-to-wing tip formation which would yield about 80 percent of the total three-plane maximum pressure pulse, moving the maximum values up to those shown in the Summary. A value of 5 psi is believed adequate to cause a moderate percentage of broken eardrums. Since the airplane signature is a combination of shocks off nose, inlet, wing, and tail, it has much more duration than say, the single shock off a bullet. This pattern also makes the addition of several patterns simpler.

Damage assessments rely on the touch point that damage actually made by aircraft corroborates that predicated from small nuclear blasts. At Tonopah, the damage from a flyby which almost certainly could not have been over 0.4 psi (and possibly was only 0.2 psi) appeared about the same as that from 0.4 psi from a small nuclear blast, say 1 kt. Possibly the multiple shocks tend to equal or even exceed the damage from the same overpressure from a small weapon.

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Analysis

Page 189 of Reference 1 gives the maximum overpressure from an aircraft as

$$\Delta p_{max} = K_1 K_2 \frac{1}{L^{1/4} h^{3/4}} \frac{(M^2 - 1)^{3/8}}{M} \left(\frac{p_o W}{\gamma}\right)^{1/2} \tag{1}$$

where

M = flight Mach number

h = height of flight, ft

L = aircraft length, ft

$K_1 K_2$ = aircraft shape parameters

p_o = atmospheric pressure, psf

W = aircraft weight, lb

γ = ratio of specific heats for air.

We see that the maximum overpressure is proportional to $W^{1/2}$, $h^{-3/4}$, $L^{-1/4}$, p_o and a function of Mach number. The Mach number function peaks at $M = 2.0$, which is not particularly helpful as flight much above $M = 1.2$ at sea level for distances of more than a few miles seems beyond the current state-of-the-art. Flight at $M = 1.2$ at sea level is attainable by both the F-4 and F-111 at moderate weights (F-4 = 35,000 pounds, F-111 = 65,000 pounds).

Data from the F-104 have been used to compute its $K_1 K_2$ value [illegible] and hence Equation (1) for the F-104 reduces for $M = 1.2$ to

$$\Delta p_{max} = 1.7 \left(\frac{L}{h}\right)^{3/4} .$$

Using this expression, and assuming that the F-104 shape parameters hold for the F-111, a table of overpressures has been computed which allows [illegible] F-111 greater weight (65,000 vs 20,000 pounds) and its greater length (75 vs 55 feet).

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$\frac{h}{L}$	Height for F-104 (ft)	Δp_{max} F-104 (psi)	Δp_{max} F-111 Same h/L	Δp_{max} 3 F-111's	Equivalent Height (ft)
1	55	1.70	2.84	6.82	75
2	110	0.99	1.64	3.83	150
3	165	0.75	1.25	3.00	225
4	210	0.62	1.04	2.44	300
5	275	0.51	0.92	2.20	375

There is good agreement that almost all windows above 2.0 square feet in area are removed by 1.0-psi overpressure from aircraft. If the 1-kt correlation holds, we find that building damage is substantial for weak buildings over 2.0 psi, which also damages parked aircraft. Some eardrums are broken at 5 psi. People are thrown about and badly hurt from 6 to 12 psi. Thus pressures from a single F-111 probably are more of a harassment than preventing a dedicated soldier from fighting, with two exceptions. The window breakage in cities, particularly on cold days when pipe freezing will add to the confusion, could seriously hamper a nation's war effort, particularly since vast areas can be incapacitated. A dozen F-111's flying abreast across our eastern megalopolis could pretty largely put the Country out of coherent action.

A second type of attack would be to sweep very low (25 to 50 feet) over small boats. The ear pain, crushing of weak structures, and flying glass (if any) would seriously deter any smugglers from continuing their profession. In addition, one does not have to see the targets to destroy them. Flying up a river at low altitude close to the river bank is almost as bad as flying directly over the miscreants. They might be hidden to the eye, but not to Δp.

Mobile targets, people, wheeled vehicles and the like are vulnerable more to wind (= dynamic pressure) than to static overpressure. However, there is a dynamic pressure that corresponds to each static overpressure. In general, people and vehicles need repairs after the overpressure and blast corresponding to $\Delta p = 6$ psi.

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There are two methods by which the overpressures from an F-111 can be increased:

1. Accelerating as the target is reached. High altitude sonic booms are more than doubled; nothing is available as to the effect at low level, but the prospects are exciting.

2. Several F-111's could fly a wing tip-to-wing tip formation. While this might sound difficult to nonpilots, it by no means sounds impossible to pilots. Values of 5.0 psi and more are possible by a three-plane F-111 formation.

3. Rocket boost could increase the speed, provided the airframe could take it.

Several geographical circumstances mitigate for and against employing a shock sweeper. The flatter the countryside the easier it is to fly low, and indeed most cities are fairly level. Flight over water is particularly attractive, and sweeps up rivers would catch small boats and people hidden by the banks. Mountainous terrain is obviously poor for low level flight, and a jungle canopy would surely greatly weaken a shock wave. A person throwing himself flat as he sees a plane approach would be exposing himself to additional overpressures through shock reflections.

Conclusions

The weight and performance of a single F-111 puts it into the range of easily producing catastrophic damage against cities and structurally light war targets. Three F-111's accelerating in wing tip-to-wing tip formation, would develop overpressures sufficient to injure personnel through breaking some eardrums, or at least causing pain, and by throwing people about. The overpressures and blast are also sufficient to damage some radar or other vans and some wheeled vehicles, and possibly to trigger land mines.

The advantages of an overpressure attack particularly include the enormous area swept in a single flight and the lack of a need to see a target. In addition, it makes possible for the first time to "whip" a populace, crossing and recrossing an area day and night.

The disadvantages are, of course, sweeper vulnerability, a problem diminished by night flying using the terrain avoidance radar, or, later, unmanned aircraft.

Recommendations

The implications of shock sweeping are so important that it would seem worthwhile to pursue the subject to a yes or no conclusion. Accordingly, an effort will be undertaken to get more aircraft damage data, possibly at Nellis or TTR, and simultaneously take a further look at the difficulties of the low level formation flight. Any contributions from readers would be welcome.

Reference

1. Anonymous, Second Conference on Sonic Boom Research, NASA SP-180, May 1968, p. 186.

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