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PRECISE GUIDED AIRCRAFT BOMBS

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A b s t r a c t :

The paper deals with aircraft bombs with precise guidance systems. There is given the survey of trends, regarding the precise guided aircraft bombs with respect to the most convenient effect in the target, as well as the suitable aircraft carrier for the purpose assumed. The trends as well as construction arrangement correspond to the experiences gained from the latest war activities.

The bombing accuracy together with the plane safety is therefore very important characteristic of contemporary air forces.

1. General Introduction

Advance in the bombardment strategy together with its accuracy had been the result of difficult detection and the discoverable airplanes and mainly the accurately guided bombs being determined against the ground targets.

The bombs of the mentioned kinds were firstly used in the Gulf war in the year 1991. These kinds of bombs comprised approximately 8 % from all used types of the bombs and ground to ground missiles. During the Allied Force operation in the year 1999 the proportion of accurately guided munitions was more as 1/3 (i.e. 35 %), but by these

bombs were damaged approximately 74 % of the targets. Afghanistan war in the year 2001 (Enduring Freedom Operation) had been the limit because the precisely guided munitions ("*intelligent"* aircraft munitions) overcame the half (of about 60 %) of used bombs. During Iraqi war the portion of precise munitions had reached about 68 % [1].

The armament of contemporary armies at present time contain big amount of the precisely guided munitions against ground targets. The attention is turned to the laser guided bombs, bombs with television, infrared and satellite guidance systems.

The first precise guided bombs were used by USA air forces in Vietnam War, i.e. the bombs of *PAVEWAY I* series. The laser guided bombs thrown away from F – 14 planes had destroyed the Than Hoa Bridge. The amount of these bomb types (approximately 25000 pieces) can be considered rather as improvised. These weapons of the *1st generation* were thrown from the height 3000 m during day light only, regarding the properties of reflector feed. In the next years were improved the bombs itself and the properties of reflector feeds by laser beam. During the Gulf war were at disposal the precise guided systems with laser and television as well as infrared guidance systems. Approximately half of them were the precise guided bombs *PAVEWAY II* and *PAVEWAY III* series.

Fig. 1. The aircraft bomb of the PAVEWAY type

It was declared that the probability of the target hitting was assumed to be 80 %, when the laser guided bombs of the type *PAVEWAY* were used by planes F – 117A. Some years after this statement the percentage of the target hitting had been lowered till 50 %, i.e. the target was hit by every second bomb.

2. Guided Bombs

For the precise guided aircraft bombs are applied different types of guidance. One of main important guidance system is the laser system.

The laser energy is intercepted by the detector, placed in the bomb nose and the trajectory correction is secured by four aerodynamic vanes (control areas) placed also in the front part of the bomb construction. The bombs of the series *PAVEWAY II* were introduced into the armament at the end of the 70th years. These bombs are used for the destruction of different stationary targets. The maximum bomb range when thrown away from the most convenient height is of about from 10 km till 15 km**.** The bigger bomb range belongs to the bombs with the biggest mass. The principle of these types of bombs contains *front* and *rear* part, attached to the standard unguided aircraft bombs. There are several variants of these weapon systems, which differ by the used standard bomb. The heaviest type is the bomb marked as *GBU - 10*. Its main construction part is the fragmentation-demolition bomb *Mk-84*, having the mass 907 kg. The bomb length is 4.32 m; the bomb body diameter is 0.45 m. The span of the folding aerodynamic stabilising areas is 1.7 m and its overall mass is 944 kg. The bomb is shown in Fig. 2 [2].

Fig. 2. Aircraft bomb GBU - 10

The bomb *GBU – 12* represents the next type. The basic part of this bomb type is the bomb *Mk-82*, having the mass 227 kg. GBU - 12 has the length 3.33 m, the span of folding aerodynamic areas reaches 1.32 m and its overall mass is 275 kg [3]. *GBU - 12* were used during Allied Force operation in Balkans in the year 1999, as well as in Afghanistan and finally in Iraqi war. There was thrown from airplanes totally of about 7114 pieces – see Fig. 3**.**

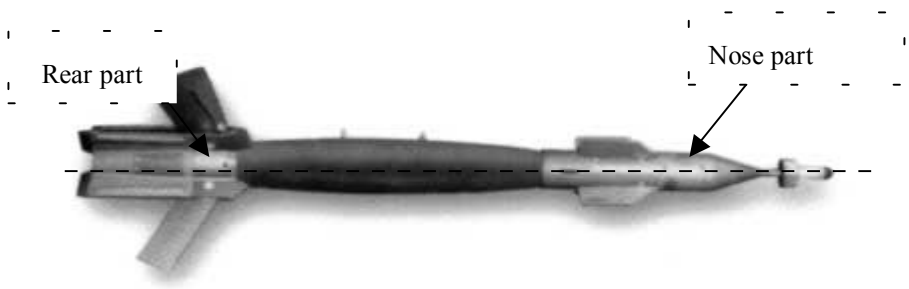

Fig. 3. Aircraft bomb GBU - 12

The *PAVEWAY II* system is also used for the aircraft bombs of the new generation bombs called as *BANG* (**B***ombe* **A***éronavale de* **N***ouvelle* **G***éneration*) by the French military Navy. They are produced in the two categories, i.e. 1st with the mass 125 kg and 2nd with the mass 250 kg. The weapon system is used by the planes *SUPER ETENDARD*, being on board of the aircraft ship *CHARLES DE GAULLE* and in the near future will be the armament of the planes *RAFALE - M*.

The 3rd generation of the laser guided aircraft bombs, i.e. the series *PAVEWAY III* which differs from the previous series by the microprocessor, controlled autopilot (is able to satisfy the flight conditions and the regime of throw away) and further on by the more sensitive nose sensor and aerodynamic areas with higher lift force. The result is the better operation ability and possibility to throw away the bomb from the lower heights, as well as the better bomb range, i.e. till 18 km. The typical bomb is *GBU - 22/B*. The principle construction part is the bomb *Mk-82*, having the mass 227 kg. The bomb arrangement is shown in Fig. 4 [1], [2].

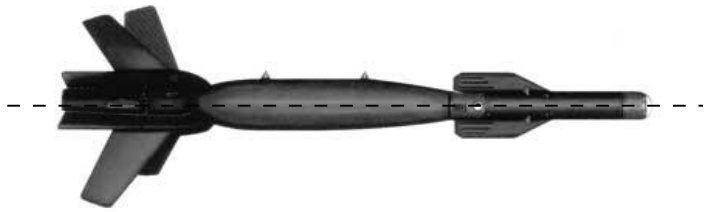

Fig. 4. Aircraft bomb GBU - 22/B

The other types of the aircraft bombs which belong to this category introduce the Table 1.

Tab. 1

Types of GBU Bombs

TYPE OF BOMB	LENGTH (M)	BOMB MASS (KG)	BASIC CONSTRUCTION PART	TYPE OF AIRCRAFT
GBU – 24/B	4.34	1050	Mk-84	F-15E, F/A-18E, F/A-18C/D, F-14, F-16, Tornado, Rafale, Typhon
GBU – 27/b	4.24	985	-	F-117A, B-1B
GBU – 28A/B	5.8	2130	-	F-15E, B-2

Further works carried out in the sphere of the aircraft bombs modernisation has started in Great Britain, i.e. the series *PAVEWAY IV*. The result of these activities can be seen in the most modern bomb of the *EGBU* type. These bombs should have high accuracy and serviceability during all climate and light conditions, as well as the broad operation ability. The pilot will have according to the real situation the possibility to choose the guidance regime, i.e. by the *laser beam* and the utilisation of the *inertial navigation system* with receiver GPS of the 2nd generation.

Due to the combined guidance system and the improved gliding ability of the *PAVEWAY IV* system should secure the possibility to attack the movable targets or could change the target. The bomb will have the new combat part with the mass 227 kg, together with "*smart (sophisticated)*" electronic fuse, which would secure maximum destroy effectiveness against the different targets. The weapon system had been probably introduced into the armament during 2006/2007 years and carriers will be the planes *TORNADO GR4/4A, HARRIER GR9/9A* and later on also the plane *TYPHOON*. Modernised bomb EGBU is shown in Fig. 5 [2].

Fig. 5. Modernised bomb EBGU – 27

The modernised bomb with system *AUP* (**A***dvanced* **U***nitary* **P***enetrator*) is shown in Fig. 6.

Fig. 6. Modernised bomb with AUP system

The progress in precise guided bombs was also started in Israel too, where were developed series of the precise guided weapons called as *WIZARD*, i.e. the guidance systems determined for connection with classical bombs as *Mk-82, Mk-83, Mk-84* and the bombs of Israeli production. The *WIZARD* system contains two basic modifications, i.e. the 1st modifications are the aircraft bombs with *infrared* guidance system *OPHER* and the 2nd modification are the bombs with *laser* guidance system *LIZARD*. Both the systems were subsequently modernised. Therefore contemporary system *LIZARD III* is probably able to hit with very high accuracy the stationary targets, as well as the movable targets (of about 1.5 m). The newest design is completed by *INS/GPS* system and is marked as *LIZARD IV*. Bomb *LIZARD* is shown in Fig. 7 [4].

Fig. 7. Israeli's laser guided bomb LIZARD

Modernised variant of the standard bomb-type *Mk-84* i.e. so called **N***ext* **G***eneration-* **L***aser* **G***uided* **B***omb* – (*NGLGB*), e.g. the bomb *M-2000*. The bomb has dual initiation system and perhaps the higher armour-piercing effect is about 70 % bigger when compared with *Mk-84* bomb. Further modified bomb to which the *NGLGB* system is attached is the armour-piercing bomb *PB-500*, having the mass approximately 227 kg, being able to pierce 2 m thick reinforced concrete wall. The bomb *PB – 500* is shown in Fig. 8 [4].

Fig. 8. Israeli's laser guided type of NGLGB, the bomb PB - 500

The development in France is known under the name *BGL* (**B***ombes á* **G***uidage* **L***aser*) and the precise guided bombs were introduced in the armament in the year 1985. As the first modification introduced into the armament was the modification connected with classical fragmentation bomb, having the mass 400 kg. The bomb length is 3.55 m and the mass 470 kg. The bomb range when thrown away from very high altitude is of about 13 km. At the beginning of the year 1990 in the armament was introduced the bigger variant of the bomb, having the mass 1000 kg. The weapon system is also known as *ARCOLE*, the length of which is 4.37 m, the mass is 970 kg and the folded stabilizing areas have the span 1.7 m. *ARCOLE* is able to be thrown away from the altitude 7500 m and to cover the bomb range of about 10 km. The piercing bomb variant which was produced later on and having the mass 400 kg was derived from *ARCOLE*, as well as was produced the variant of standard fragmentation-demolition bomb having the mass 250 kg. The throw away of the French BGL bomb is shown in Fig. 9 [4].

Fig. 9. Throw away the French bomb of BGL type from the Jaguar aircraft

In the late USSR had been started the domestic development of the precise guided aircraft bombs, having the name *KAB* (**K***orrektirujemaja* **A***viacionnaja* **B***omba*) at the beginning of the year 1970. The 1st type was the *KAB-500L* bomb, introduced into the armament in the middle of the 70th years. The length of the *KAB - 500L* bomb is 3.05 m, the body diameter is 0.4 m and the total mass is 535 kg. In contrary with the bombs produced in the other countries, the flight correction is performed by *movable aerodynamic* areas in the rear part. Beside the basic arrangement with fragmentation effect, having the mass 380 kg is also known the arrangement with the *container* arrangement, marked as *KAB-500KL*.

The bombs of the *KAB-500* type have the maximum bomb range till 10 km and form the armament of the planes *MiG-27K, Su-22M3/M4, Su-24M* and *Su-25*. The Russian bomb *KAB – 500* is shown in Fig. 10.

Fig 10. Russian laser guided bomb KAB – 500L

The other types of Russian precise guided bombs are introduced in the Table 2.

Tab. 2

Russian Guided Bombs

TYPE OF BOMB	LENGTH (M)	BOMB DIAMETER (M)	BOMB MASS (KG)
KAB -1500L - F	4.6	0.58	1560
KAB – 1500L - Pr	4.6	0.58	1100
KAB – 500Kr	3.1	0.35	520

The bombs of the *KAB – 1500 series* according to known information can be thrown away from the altitudes from 1 km till 15 km. The maximum bomb range from very big altitude is (18 ÷ 20) km. The hitting accuracy can be 7 m and less.

The precise aircraft bomb *KAB - 500Kr* with *television* guidance system has been fielded within the 70th up to 80th years. There is also at disposal the precise bomb *KAB-500Kr-Od* with *liquid explosive*, determined for destruction of the big area targets.

Bomb *KAB – 1500Kr* is shown in Fig. 11.

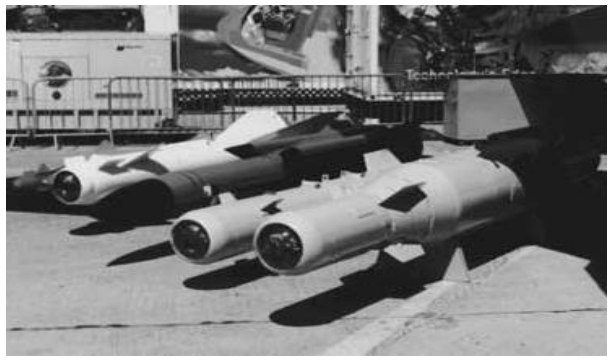

Fig. 11. Russian aircraft bomb KAB – 1500Kr

The laser guided aircraft bombs results in substantial turnover in the accuracy and the manner of ground or navy targets destruction. Their point accuracy (standard deviation is in several meters), but there are also some disadvantages. Beside their relatively higher price there is the necessity of every target irradiation during the total time of flight of the bomb. Therefore there had been searched another solution, which was discovered in the USA after finishing *Desert Storm* operation, i.e. by the new system marked as *JDAM – (**J**oint **D**irect **A**ttack **M**unitions)* [4].

The origin of these systems was the result of progress in the miniaturisation of the **I***nertial* **N***avigation* **S***ystems* - (*INS*) and progress in the satellite system *NAVSTAR* for the precise determination of the position (*GPS*). The needed data were put into the board system from the weapon computer of the aircraft, shortly before the bomb thrown away. The standard deviation was approximately of about (45 ÷ 50) m. The addition of the GPS receivers, which transfer during the flight corrective data to the *INS* system regarding the bomb position and results in many times increased accuracy of the target hitting. The combination of both the mentioned means forms the base and decisive category of the *JDAM* guided bombs types.

The development of the weapon system *GATS* (**G***PS* - **A***ided* **T***argeting* **S***ystem*), for aircrafts *B-2A* was started in the year 1993. The *GATS* system elaborates and combines information's received from the satellite system *NAVSTAR*, as well as from the board radar with the high discrimination ability (*SAR*). Therefore the equipment allows the determination of the target on the arbitrary Earth position. For the *GAM* (**G***PS* - **A***ided* **M***unitions*) had been developed the special bombardment system. The principle part of the system mentioned, i.e. the classical unguided bomb *Mk-84* having the mass 907 kg and provided by rear part containing the movable vanes together with guidance system using the *INS* and *GPS*.

US air forces have at disposal the following types of bombs, i.e.:

- *GBU – 36/B;*
- *GBU – 37 of the big calibre (sometimes marked as GAM – 113 – mass 2130 kg).*

In the time being are these bombs replaced by the *JDAM* bombs.

The *JDAM* bombardment system is produced as special kit by means of which can be modified the classical unguided bombs into the guided ones. The kit represents new rear part, having the four movable stabilizing areas (vanes) and guidance system (*INS* and *GPS*). The middle part represents the electric connection with the plane and the quaternion of longitudinal lift ribbons, which improve the bomb stability and the bomb gliding flight for a long distance (when thrown away from high altitude till 25 km). Special kit is shown in Fig. 12 and Fig 13 [4].

The bombs of the *JDAM* type have several advantages. Their utilisation isn't influenced by the clouds, smoke or the other climate and light conditions, but they have also some disadvantages. Their accuracy when compared with the laser guidance system is less and is called as *NPGM* bombs (**N***ear-***P***recision* **G***uided* **M***unitions*). Their accuracy reaches the value of the target hitting (6 ÷ 11) m, i.e. the under determined limit of 13 m as it was required in the original demands.

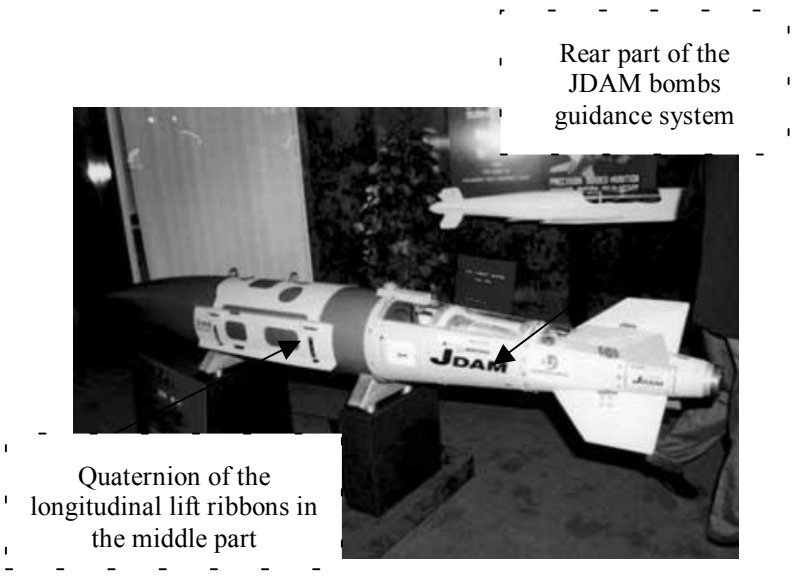

Fig. 12. The rear and middle part of the JDAM bombs

Fig. 13. The elements of the JDAM bomb guidance system associated with the Mk-83 bomb

In the time being there are known four variants of the *JDAM bombs* – see Table 3.

Tab. 3

Variants of JDAM Bombs

TYPE OF BOMB	LENGTH (M)	MASS (KG)	TYPE OF BOMB
GBU – 31 – for Air forces	3.875	924	Mk-84
GBU – 31 for Navy	3.775	933	Mk-84
GBU – 32	3.035	460 (for air forces) 466 (for NAVY)	Mk-83
GBU - 35	3.035	455	BLU-110 piercing effect
GBU - 38	-	227	Mk-82

The new program of the precise guided bombs of the latest generation is called **S***mall* **D***iameter* **B***omb - (SDB)*. It is evident that the development program deals with the bombs, having *small diameter* and *short* length, as well as the *small mass*. The mass is presupposed to be about 115 kg. With respect to the high accuracy of the target hitting seems to be sufficient and in some cases also more advantageous. The more targets according to gained experiences are in built-up areas so that the relatively light bomb of *SDB* type due to the precise guidance has the sufficient destructiveness and together with non required claims near to the target hit. The another reason of *SDB* bombs development, is their external dimension, which allows to place the bigger number of these bombs into the inner aircrafts bomb containers of the planes *F-35, F-117A*, or *F-22* and the developed *UAV* (**U***nmanned* **A***ir* **V***ehicles)*.

The program of the precise guided munitions in France is related to the new generation of bombs called as *AASM* (**A***rmament* **A***ir-***S***ol* **M***odulare*). By the *AASM* system would be provided the standard bombs, having the mass 125 kg, 250 kg, 500 kg and 1000 kg. The aircraft carriers should be the aircrafts *MIRAGE 2000* and *RAFALE*.

Another new type of the precise guided bombs is the system *SPICE* (**S***mart* **P***recise* **I***mpact and* **C***ost-***E***ffective Guidance Kit*), being determined for the modernisation of the standard aircraft bombs. The bomb of *SPICE* type due to its aerodynamic solution is able after thrown away from the height 13 km to glide to the distance of about 60 km. The bomb of *SPICE* type after thrown away allows attacking the targets from long and safe distance and is guided autonomously. The bomb is practically during the time of its flight guided by the *board inertial navigation* system along the determined path of flight.

The bomb of *SPICE* type has the length 4.2 m, the total mass 1065 kg and its basic construction part is the bomb *Mk-84*, having the mass 907 kg. According to available information the bombs of *SPICE* type when compared with majority of the precise guided bombs have some advantages, as e.g. they have very long bomb range and in

comparison with the *JDAM* bombs are more precise and in comparison with the laser guided bombs aren't influenced by climate conditions.

The development of the aircraft bombs of the *OPHER* type has been started at the beginning of 80th years. The bombs of this type are solved again as a certain kit, i.e. they have the rear and the front part. The front part contains the guidance system, quaternion of aerodynamic vanes and the infrared guidance system with cooled head detector. The rear part contains folding areas, having purely the *stabilizing* and the *lift* function. The bombs of the *OPHER* type don't require any *laser marker* and can be applied during the different air attacks. The *OPHER* system has the length 3.4 m and the mass 325 kg.

Further new aircraft bombs belong to the *WCMD* (**W***ind* **C***orrected* **M***unitions* **D***ispenser*) system determined for retrofitting of the cluster bombs *CBU-87, CBU-89* and *CBU-97* for the more precise guidance in order to determine the most convenient opening of the cluster. The all important parts are located in the new rear part, which can be attached to the standard cluster bomb. The rear part has the length approximately 0.5 m and the mass 45 kg and it contains miniature inertial guidance unit, the quaternion of movable areas, and the microprocessor with special algorithms for the wind compensation.

The *WCMD* system is used for the three types of the unguided cluster bombs. Their main parameters are shown in the Table 4.

Tab. 4

Types of Unguided Cluster Bombs

TYPE OF CLUSTER BOMB	LENGTH (M)	MASS (KG)	CONTENT OF SUBMUNITION	COVERED AREA (M)
CBU -87 (with WDCM – CBU – 103)	2.37	430	220 (BLU-97)	240x120
CBU – 89 GATOR (with WCMD – CBU-104)	-	310	72 antitank mines; 22 anti troop mines	Mine fields
CBU – 97 (with WCMD - CBU105)	-	420	72 pieces of submunition provided by sensor fuzzed weapon	(150 ÷ 200) - width (350 ÷ 400) length
CBU - 107	similar to CBU-103 or CBU - 105	similar to CBU-103 or CBU – 105	350 pieces of arrows – 0.355 m length 2400 pieces of arrows – 0.178 m length 2400 pieces of steel arrows –of 0.051m length	

3. Conclusion

The content of the paper presented and being mentioned above is related to the modern types of the precise guided aircraft bombs. The individual described types of the precise guided bombs introduce mainly the trends in the development of these weapon systems as it flows out from the experiences collected during the last (10 – 15) years of the war activities.

Another reason of this paper is to introduce the knowledge being necessary for the decision, which type of the bombardment equipment should be searched for the new aircrafts of Czech Air Forces, in order to be on the level of the latest experiences, regarding the supersonic JAS – 39 Gripen as well as L - 159 Alca aircrafts.

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