Historic Weight Growth

of

U.S. Army Combat Vehicle Systems

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Military Traffic Management Command
Transportation Engineering Agency
720 Thimble Shoals Boulevard, Suite 130
Newport News, VA 23606-4537

LTC Timothy P. Clapp
clappt@tea-emh1.army.mil
(757) 599-1630/DSN 826-4643

Mr. Joseph F. Cassidy
cassidyj@tea-emh1.army.mil
(757) 599-1630/DSN 826-4643

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General:

As the Army prepares to usher in a new family of combat vehicles, it is important to review the weight growth history of past combat vehicles. The purpose of this review is to ensure that lessons learned from these past programs are applied to current and future acquisition programs. The Army has developed, fielded, and upgraded several families of combat vehicles over the past four decades. All have experienced significant weight growth over time. This weight growth contributed to the increase in the Army's deployment footprint over the years and affected the transportability of the individual systems. While the effect of weight growth may be most visible during air transport, it affects all modes of transportation. This paper concentrates on air transport, but also discusses several critical adverse effects on other modes. The specific systems that this paper reviews are the M113-series, Armored Personnel Carrier; the M2/3-series, Bradley Fighting Vehicle System (BFVS); the M60-series, Main Battle Tank (MBT); the M1-series, Main Battle Tank; and the High Mobility Multipurpose Wheeled Vehicle (HMMWV). Current and emerging doctrine for the interim and future combat forces calls for systems to be deployed in a ready-to-fight, or combat loaded configuration. Therefore, this paper focuses primarily on the combat-loaded weights of these systems.

A changing threat environment and advances in technologies are the two biggest factors in tactical vehicle weight growth. These two factors drive the need or the opportunity for increased survivability, lethality, and automotive performance (speed and power). In the 1980s, the Army put appliqué armor, a new technology, on select combat vehicles in response to more lethal threat tank rounds, providing a significant increase in survivability. Appliqué armor also led to a significant weight growth for the BFVS. In the 1990s, the Army upgraded the gun on the M1 from 105mm to 120mm in response to more advanced threat armor, thus increasing the tank's lethality and weight. Finally, to improve speed, power, and mobility, each model upgrade of the M113 included a larger, more powerful, heavier engine. These factors are not likely to change in the future.

The key vehicle characteristics that influence system air transportability are weight, size, and floor-loading, measured in pounds per square inch (psi), pounds per linear foot (plf) of track length in contact with the aircraft floor, and axle loads. System weight affects several factors – whether the system can be transported or not, how many systems can be transported in a single sortie, and how far the aircraft can fly before refueling. Size affects whether the system can be transported with or without reduction, how many systems can be transported, and, in some cases, whether shoring is required for loading and/or flight. Finally, the floor loading affects whether the system will require loading and/or in-flight shoring, as well as the location within the aircraft the system can be loaded. This paper focuses primarily on weight growth, as it is the system characteristic that has historically undergone the greatest growth over the life cycle of the systems analyzed.

Weight growth rarely prohibits a vehicle from being transported on an aircraft. More frequently, the weight growth causes a decrease in the range of the aircraft. Aircraft range, however, is extremely important when it comes to the issue of tactical utility. If a vehicle can be transported only 100 nautical miles in an aircraft, yet the tactical mission for the vehicle requires a range of 500 nautical miles, then transporting that vehicle by air may not be feasible. This frequently leads to disassembly or off-loading of mission essential components of the vehicle, and splitting the load between two aircraft, thus significantly increasing sortie requirements. Another effect of weight growth is the decrease in aircraft density loading. The increase in vehicle weight decreases the number of vehicles that could be transported on a single aircraft.

M113-Series, Armored Personnel Carrier

The M113-series, Armored Personnel Carrier was first fielded in the late 1950s. Chart 1 shows the evolution of the M113-series of vehicles' combat-loaded weight from the basic M113 to the M113A3. The M113-series has grown in weight by 23% over the system's life. Because

M113A1, Armored Personnel Carrier

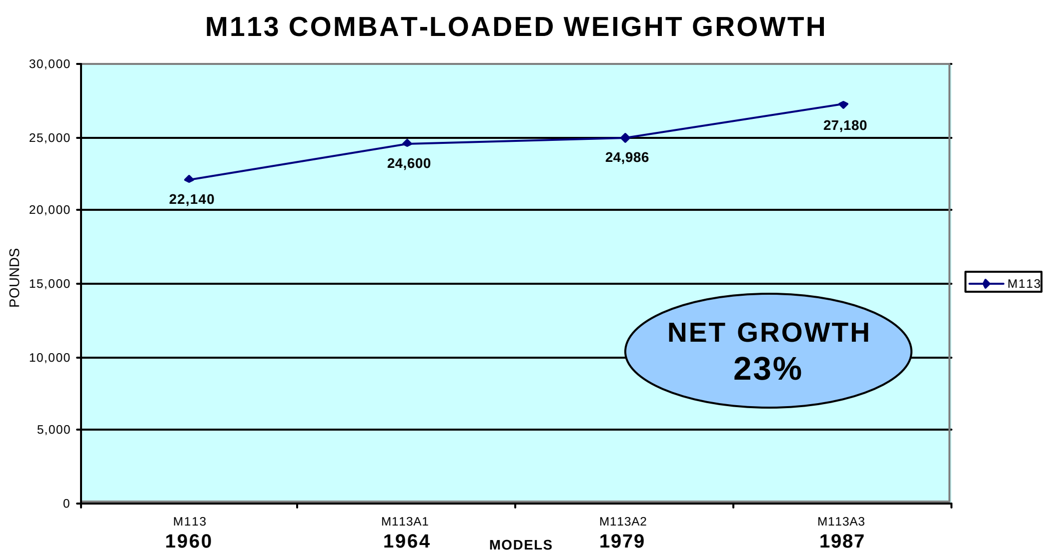

Chart 1

of its relatively low weight, the M113-series is transportable in the C-130 and has presented few air transportability challenges, even with the 23% weight growth. The M113-series weight growth did not seriously affect the tactical use of the aircraft, and the frequency of C-130 transport was very low. The weight growth, however, contributed to the increase in the total weight the Army must deploy, and is illustrative of system weight growth.

Bradley Fighting Vehicle System (BFVS), M2/M3

It's not only weight growth for a particular system that creates transportability problems, but weight growth between systems, as the Army transitions to a modernized system to meet an existing battlefield function. For instance, the BFVS replaced the M113 in many units, but could not be transported aboard the C-130. Though the BFVS was designed to be air transportable on the C-141 cargo aircraft, the weight growth of the A1 model effectively precluded the BFVS from transport aboard the C-141. Finally, with the introduction of the C-17, the operational requirement for transporting the BFVS in the C-141 was withdrawn. The predecessor system, the M113, could be transported in both the C-130 and the C-141.

For highway transport, two M113s could be transported on the M872 flatbed trailer, a generally available transportation asset. However, the BFVS requires an M870 lowbed semitrailer, an engineer asset not generally available to non-engineer units, or the Heavy Equipment Transporter System (HETS), which is a dedicated main battle tank transport system.

Similarly, with rail transport, four M113s could be transported aboard an 89-foot railcar with four half-inch alloy steel chains per vehicle. The BFVS is too heavy and wide to be transported on the 89-foot railcar and is limited to two on a 60-foot railcar. The BFVS, also, requires 12 to 16 half-inch alloy steel chains to properly tie down each vehicle. Thus, units that received the BFVS to replace the M113 had more difficulty obtaining highway transport assets, required more railcars for rail transport, and required significantly more time to prepare the BFVS for rail transport.

The BFVS has never had a problem being transported in the C-5 or the C-17. As shown in Chart 2, the BFVS quickly grew to over twice the weight of the heaviest M113 and eventually

M2, Bradley Fighting Vehicle System

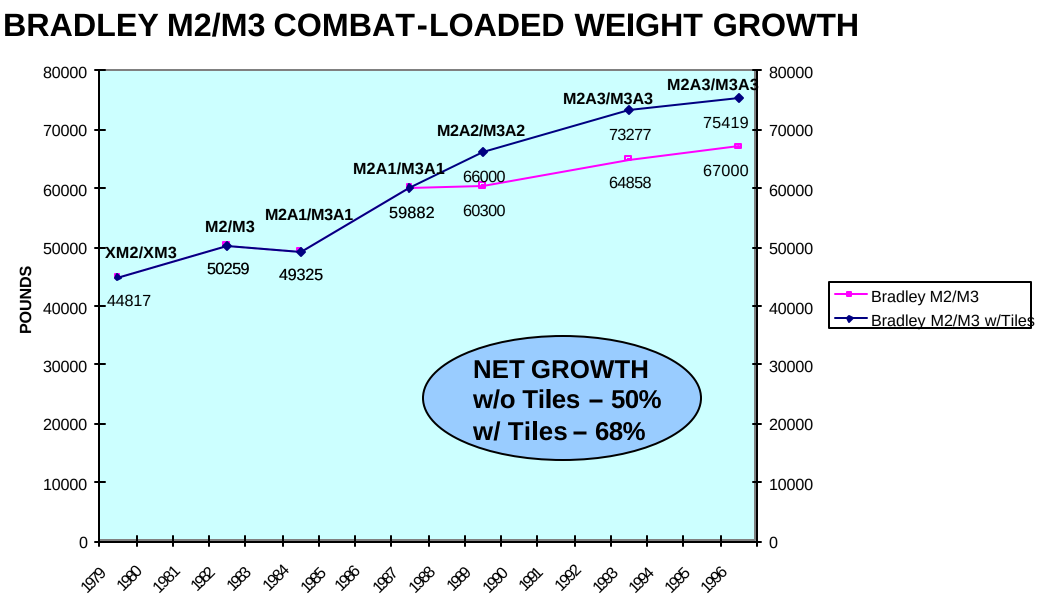

Chart 2

grew to over three times the heaviest M113's weight. This led to increased sorties required to transport units that had the BFVS replace their M113s.

In 1991, with the heaviest BFVS model weighing 66,000 pounds, the Army, anticipating future weight growth, requested a weight limit of 75,000 pounds for transport in both the C-5 and C-17. Currently, the heaviest combat loaded model has exceeded that weight by 419 pounds.

The weight growth of the BFVS is shown in Chart 2 by two lines, for versions of the BFVS with and without tiles. Over its life, the BFVS has increased in weight by 68% (with tiles) and 50% (without tiles).

M60-Series, Main Battle Tank

The combat-loaded M60 Main Battle Tank has presented few problems from an air transportability perspective because it has always been too large/heavy for the C-130 and C-141. When it first entered service in 1961, there were no U.S. military cargo aircraft that could carry the M60. It was not until the fielding of the C-5 in 1970 that the U.S. military had the capability to deploy an M60 Main Battle Tank by air.

As shown in Chart 3, The M60-series grew from an initial combat loaded weight of 101,000 pounds to its final weight of 113,000 pounds without appliqué armor and 123,729 pounds with appliqué armor, weight growths of 12% and 22.5%, respectively.

For strategic deployment planning, a critical leg of 3,200 nautical miles is generally used. The critical leg is the longest leg the Air Force needs to deploy across the Atlantic and Pacific Oceans and reach designated refueling bases. The C-5 can fly a payload of about 178,000 pounds a distance of 3,200 nautical miles. The C-5 could always transport one combat loaded M60-series tank a distance of 3,200 nautical miles. Transport of two M60 series tanks was possible at shorter strategic ranges, but only for specific scenarios requiring additional refueling stops or, in an emergency situation, aerial refueling.

M60A1, Main Battle Tank

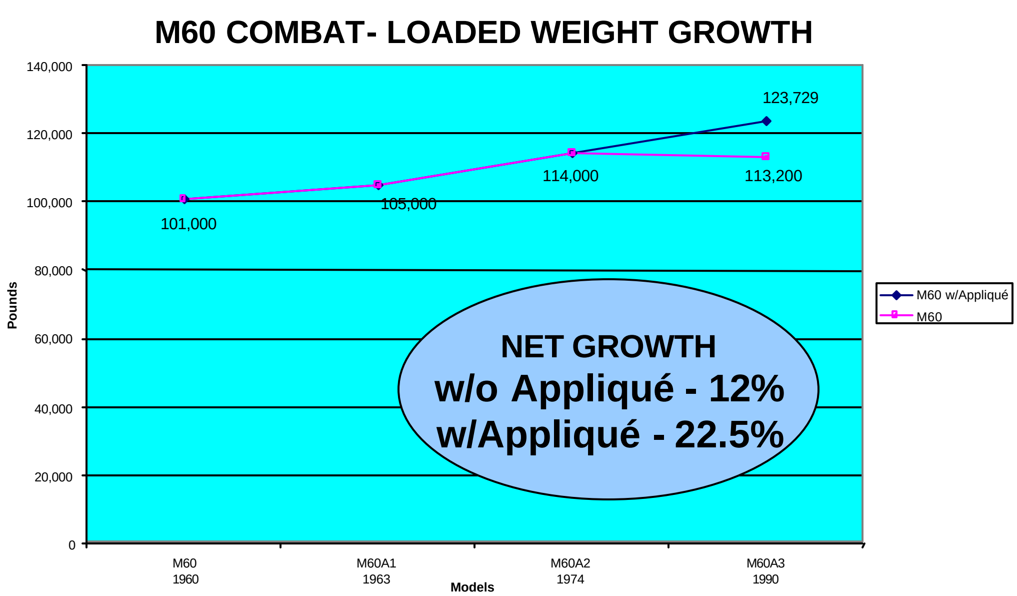

Chart 3

M1 Abrams, Main Battle Tank

The XM1 began at a weight of 108,000 pounds in 1975. By 1985, the M1A1 had exceeded the weight of the heaviest M60 model, which it had replaced in many units. As shown in Chart 4, the M1 Abrams has grown to 137,400 pounds, an increase of 27%.

The heavier M1 caused significant transportability problems for highway and rail modes of transport, as well as for transport aboard Army watercraft. The Army had to develop a new Heavy Equipment Transporter System to carry the M1 and had to upgrade the M88 heavy recovery vehicle to accommodate the heavier M1. The Army had to procure special railcars to transport the M1. While the M60 could be transported on both the LCM-8 and the LARC LX, the workhorses of the Army's watercraft fleet, the M1 could not be transported safely on either.

While the M1 Abrams has undergone significant weight growth during its life cycle, because it started out significantly lighter than the maximum payload weight of the C-5, it has not had any major air transport problems. For strategic deployment planning, a critical leg of 3,200 nautical miles is generally used. The critical leg is the longest leg the Air Force needs to deploy across the Atlantic and Pacific Oceans and reach designated refueling bases. The C-5 can fly a payload of about 178,000 pounds a distance of 3,200 nautical miles. The C-5 could always transport one combat loaded M1-series tank a distance of 3,200 nautical miles. Transport of two stripped-down M1-series tanks, while possible at short ranges, is generally not feasible. In an emergency situation, aerial refueling could be used to extend the range of the C-5, but this possibility should not be counted upon. Only one M1 Abrams can be transported on the C-17. Because of loading ramp weight limitations, the Abrams cannot weigh more than 134,200 pounds for loading on the C-5 and 135,000 pounds for loading on the C-17.

M1 Main Battle Tank

M1 ABRAMS COMBAT-LOADED WEIGHT GROWTH

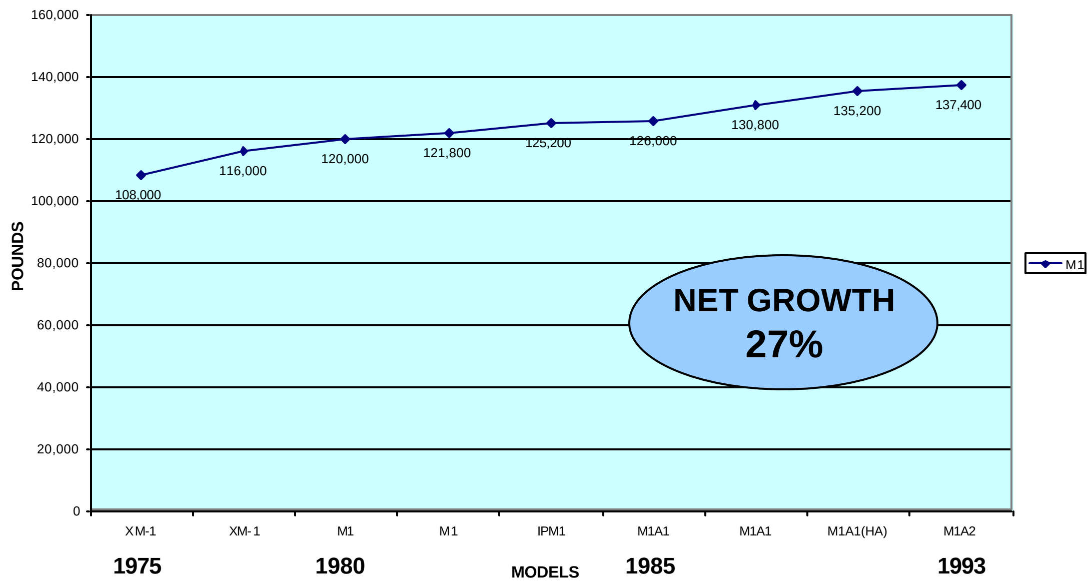

Chart 4

High Mobility Multipurpose Wheeled Vehicle (HMMWV)

The HMMWV has three general functions, each achieved by different variants – the cargo variant, the shelter carrier variant, and the armament variant (light and heavy armored versions). Each variant has its own weight growth path, with a number of HMMWV models along the way (see Charts 5 – 7, below).

The predominant transportability degradations caused by this weight growth are the ability to transport multiple combat-loaded HMMWVs aboard the C-130, and the ability to externally air transport the HMMWV with operationally significant payloads under the UH-60 helicopter. Three combat-loaded M998s, M1037s, or M1025s could be loaded into a single C-130 cargo aircraft. This was possible because the front axle loads of these vehicles were all less than 3,500 pounds, the maximum axle load allowed during flight on the C-130 ramp, assuming no other loads are on the ramp. With the fielding of the heavier HMMWV versions, beginning in 1994, the front axle loads on the combat-loaded HMMWVs exceeded 3,500 pounds. When the front axles exceed the ramp weight limits, only two of the heavier versions of the HMMWV can be loaded on the C-130. For most units, this is not a significant transportability problem. However, for many signal or intelligence units that have large numbers of HMMWV systems, many of which are mounted in shelters, this significantly increases the numbers of C-130 sorties required to move the unit.

High Mobility Multipurpose Wheeled Vehicle

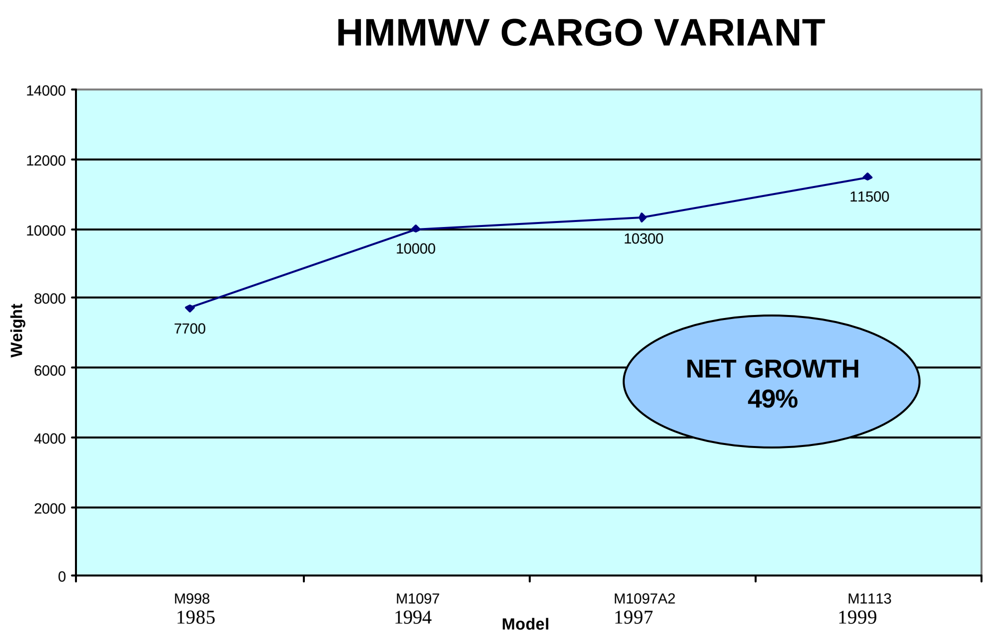

Chart 5

The UH-60L helicopter can transport a maximum external payload of 6,630 pounds up to a distance of 30 nautical miles in a high altitude (4,000 feet) and high temperature (95^{o} F) scenario. For the cargo and shelter carrier variants, from 1985 to 1999, weight growth in these two variants decreased the allowable payload the vehicles could carry for UH-60L external air transport in the high-hot scenario from 1,350 pounds to 250 pounds. In this same scenario the M1025 armament variant could carry a payload of only 530 pounds. The curb weight of the M1025A2 and the M1114 exceeded the external air transport payload capability of the UH-60L in the high-hot scenario.

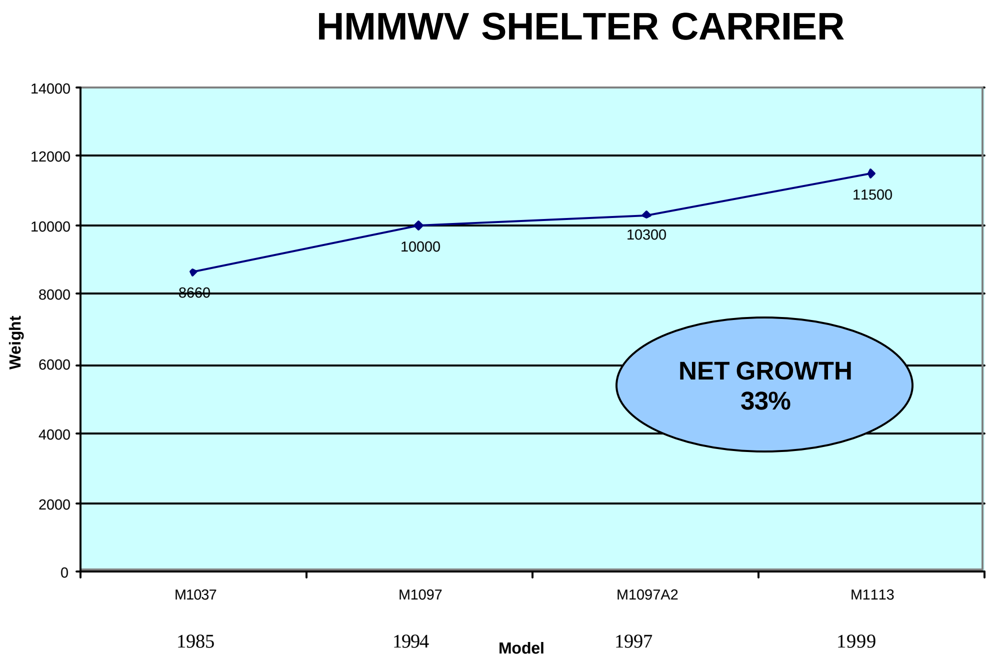

Chart 6

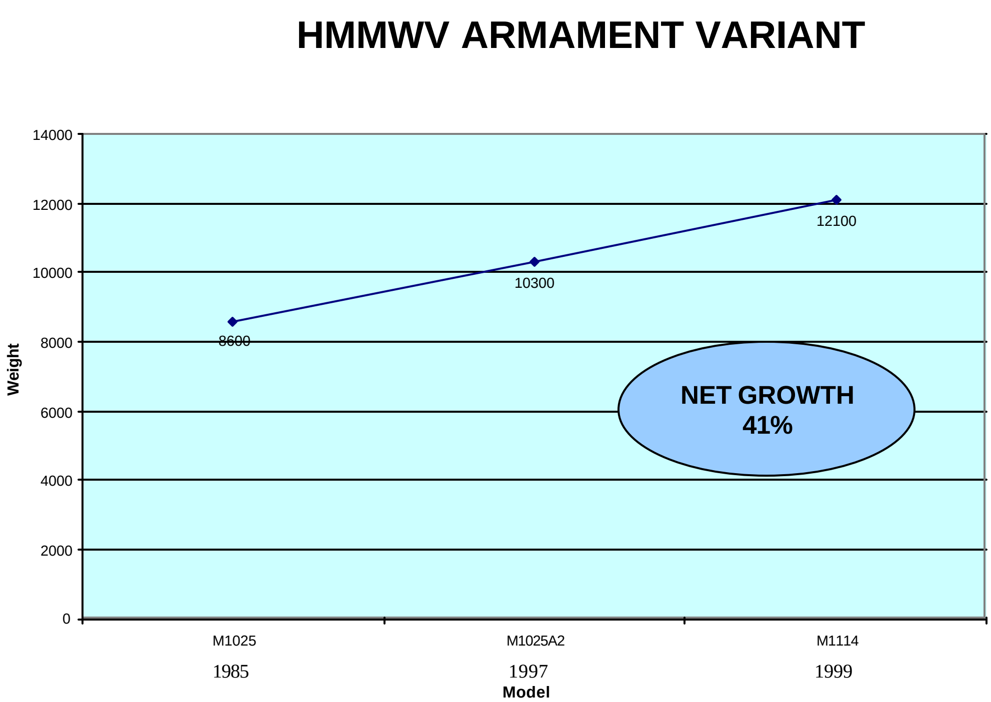

Chart 7

Discussion

With many new systems being designed to weights and dimensions very close to the maximum capabilities of the C-130, the effects of a conservative 25% weight growth would be devastating to C-130 transport. Under ideal flight conditions and with a normal landing, an armored C-130H with a 40,000-pound vehicle as payload is capable of flying 500 nautical miles, assuming that fuel will be available at the airfield. A weight increase of just 12.5% (only the M60 without protective armor tiles had such a low weight growth) would take the vehicle well beyond the aircraft's maximum payload. The following table shows the effects of 12.5% and 25% system weight growth on the range of the armored C-130H, assuming ideal conditions, a normal landing, and aircraft fuel available at the destination airfield.

Effect of System Weight Growth on Armored C-130H Range

Original System Weight (pounds)	Original System C-130H Range (nautical miles)*	12.5% System Weight Growth (pounds)	12.5% System Weight Growth C-130H Range (nautical miles)*	25% System Weight Growth (pounds)	25% System Weight Growth C-130H Range (nautical miles)*
28,000	1,540	31,500	1,340	35,000	1,120
30,000	1,430	33,750	1,220	37,500	910
32,000	1,320	36,000	1,040	40,000	500
34,000	1,200	38,250	800	42,500	40
36,000	1,040	40,500	390	45,000	0
38,000	860	42,750	30	47,500	0
40,000	500	45,000	0	50,000	0
42,000	60	47,250	0	52,500	0

* Assumes armored aircraft, ideal operating conditions, normal landing, and fuel available for aircraft at destination airfield.

Conclusion:

Over the past 40 years the major combat systems discussed in this paper all have undergone significant weight growth. This weight growth took place not only with each particular system, but between predecessor and successor systems as well. This has created transportability problems for the using units in highway, rail, sea, and air modes of transport. While the air transport problems have been minor for the most part in the past, today we are attempting to design new systems to fly in combat-ready configurations aboard the C-130, the most restrictive U.S. Air Force cargo aircraft for both size and weight. It is critical that the design of new systems allow for sufficient weight growth potential. In general, <u>developers and contractors should consider the historical numbers presented in this paper and plan for weight growth increases of 25% over the life of their system</u>.

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