TOWARD NEW HORIZONS

VOLUME 5

FUTURE AIRBORNE ARMIES

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON 25, D. C.

18 May 1955

MEMORANDUM FOR ASSISTANT SECRETARY OF DEFENSE, RESEARCH AND DEVELOPMENT
ATTN: Colonel H. J. Halberstadt

SUBJECT: Reclassification of SAB Publications

It has been determined that the attached document can be downgraded to unclassified. This has been cleared through both Air Force and Army channels. All other publications in the "Towards New Horizons" series are classified in accordance with the attached inclosure.

LLOYD J. SWEET
Lt. Colonel, USAF
Assistant Executive Secretary
Scientific Advisory Board
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2 Incls:
1. Classification List
2. "Future Airborne Armies"

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	Science, The Key to Air Supremacy	SECRET Declassified
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* Part I - "Explosives and Terminal Ballistics" entitled "General Considerations on Explosives and Explosions" by G. Gamow is a separate book and the classification remains SECRET.

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Future
AIRBORNE ARMIES

A REPORT PREPARED FOR THE AAF SCIENTIFIC ADVISORY GROUP

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The AAF Scientific Advisory Group was activated late in 1944 by General of the Army H. H. Arnold. He secured the services of Dr. Theodore von Karman, renowned scientist and consultant in aeronautics, who agreed to organize and direct the group.

Dr. von Karman gathered about him a group of American scientists from every field of research having a bearing on air power. These men then analyzed important developments in the basic sciences, both here and abroad, and attempted to evaluate the effects of their application to air power.

This volume is one of a group of reports made to the Army Air Forces by the Scientific Advisory Group.

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FUTURE AIRBORNE ARMIES

SUMMARY

Airborne operations will play a major part in the next war from the very beginning. Vital island bases and strategic outposts will have to be occupied and reinforced by air. Airborne operations deep in the enemy's strategic territory will not only be possible; they will be necessary. There must be developed the capability of deploying by air complete major combat units of the United States Army. It must be possible to do this at any time of day, under poor weather conditions, and at any practical operating radius up to 2500 miles or more, depending on the world-political situation.

Special troop-carrier aircraft must be developed for airborne armies. These aircraft must be capable of cruising at comparatively high speeds, while still retaining the ability to land and take-off at safe, low speeds from small fields. Vigorous application of jet-assisted take-off, boundary layer control, high-lift devices, and deceleration devices on troop carrier aircraft can make this possible. Carrier airplanes must also be specially designed for rapid and easy loading and unloading of bulky items of ground equipment.

Gliders were used on a large scale, and with great effectiveness, for the first time in the airborne operations of this war. The development of gliders and glider techniques must be continued, since, at the present time, this is the safest, cheapest, and most acceptable method of landing heavy equipment during the assault phase of an airborne operation. New glider developments should stress the following: adequate crash protection for crew and cargo; low landing speeds and use of deceleration devices for shortening the length of landing ground roll; rapid unloading through wide, rear-loading doors; adequate protection against small-arms fire for pilot and copilot; greater aerodynamic and structural efficiencies through the use of high-lift devices and metal construction; and the use of assisted take-off techniques for decreasing the length of take-off run required by glider-towplane combinations. New gliders (towed aircraft) must be and can be easily designed for rapid conversion to low-powered transports. This will eliminate some of the major shortcomings of gliders because ferrying to combat theaters and use as short-haul transports between airborne missions will be possible. The advantage of having such a transport, which can be easily and rapidly loaded and unloaded, for short-haul work immediately behind the lines cannot be over-emphasized. Promising new techniques for the assault landing of heavy equipment must be developed and evaluated tactically. Important among these are: the "assault transport;" the method of dropping heavy equipment by means of parachutes and decelerating rockets; aircraft with jettisonable cargo compartments; and rotary-wing aircraft. Stable (non-oscillating) parachutes with lower opening loads must be developed for paratroopers.

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There is immediate need for an overall study of the weight and dimensional characteristics of every item of equipment in the Army. Only a complete study of all Army equipment can show what types and sizes of future troop carrier aircraft are required to move the Army by air with greatest possible efficiency. Every gun, transport vehicle, tank, tractor, and other item of equipment must be air-transportable, naturally, with the exception of railway guns, heavy seacoast defense guns, and the like. However, the entire burden of making the Army air-transportable must not be allowed to fall solely on the aircraft designer. The number of different types and sizes of troop carrier airplanes developed must be kept down to a practical minimum. There must be established a means of control over the weights and dimensions of Army equipment to insure that future equipment will be capable of being carried in future aircraft. Items which do not fit in existing aircraft or in aircraft under development must be redesigned, or new items, which are air-transportable, must be developed to take their place. This can be done and must be done without compromising battlefield requirements in any way. The cargo airplane and ground equipment development programs must be coordinated at frequent intervals by an agency charged with the specific responsibility of making the Army capable of movement by air.

The potentialities of future airborne operations are unlimited, if the possibilities are successfully exploited in the future design of both aircraft and equipment. The capability of deploying major ground force units by air will revolutionize military strategy and tactics.

INTRODUCTION

This report attempts to summarize the thoughts and ideas of people in the services who are connected with the airborne program. The following organizations have contributed, either by means of reports or through conferences, to the material contained in this study:

WAR DEPARTMENT SPECIAL STAFF
- New Developments Division

ARMY AIR FORCES
- AC/AS, Operations, Commitments & Requirements
  - Requirements Division, Airborne and Liaison Branch
    - Troop Carrier Section
    - Glider Section
    - Materiel and Equipment Section
  - Army Air Forces Board
  - Aircraft Division
- AC/AS, Materiel & Services
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    - Engineering Branch, Radio and Radar Section
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  - Air Quartermaster Officer, Supply & Maintenance Branch
    - Research & Development Section
- AC/AS, Plans, Operational Plans Division
- Air Communications Officer, Equipment Division
- Air Technical Service Command (as of March 1946, Air Materiel Command)
  - Engineering Division
    - Aircraft Projects Section, Cargo Branch
    - Aircraft Laboratory; Aerodynamics, Design, and Glider Branches
    - Personal Equipment Laboratory, Parachute Branch
  - NACA Liaison Officer, Langley Field
- First Troop Carrier Command

FIRST ALLIED AIRBORNE ARMY

ARMY GROUND FORCES

G–3 Section, Training Division

Airborne Branch

Requirements Section, Infantry Branch

Airborne Representative

Airborne Center

Airborne Board

Equipment Review Board

ARMY SERVICE FORCES

Ordnance Department, Research & Development Service

Signal Corps, Engineering and Technical Service

The hard work and realistic thinking being done by these organizations has made America first in the successful, large-scale employment of airborne forces. A bold, progressive research program and a continued, open-minded willingness to try the new will give us Airborne Armies which will always be second to none.

AIRBORNE OPERATIONS

PRESENT DOCTRINE AND METHOD OF EMPLOYMENT

Airborne troops are specially trained and equipped to accomplish specific missions in coordination with major ground actions. They seize strategic objectives which are not accessible to the ground force. They seize and hold important tactical localities pending the arrival of the ground force; they attack the enemy rear and thereby assist a breakthrough by the main force; or they block or delay enemy reserves by capturing and holding critical terrain features.

Airborne troops are employed in mass, the bulk of the force being landed as rapidly as possible in as small an area as practicable. They are not employed unless they can be supported by other ground forces within approximately three days, and unless they can be withdrawn after their mission has been accomplished.

Air superiority is a fundamental prerequisite for successful airborne operations. The degree of air superiority which can be attained is a major factor in determining whether an airborne operation should be initiated during daylight or under cover of darkness.

Weather is another important factor. Large-scale troop-carrier operations demand suitable weather conditions. In the event of unexpected weather conditions, ground commanders must be prepared either to postpone launching the main attack or to operate without airborne forces.

The essential phases of an airborne operation can be summarized as follows:

1. Large portions of the strategic and tactical air forces are committed to the task of softening-up the combat area, knocking out flak installations, providing air cover along the route for the troop carrier trains, and securing local air superiority in the forward combat zones.

2. The establishment of an air head starts with mass jumping of paratroopers who seize and hold the drop zones and landing zones. Some light artillery is also dropped by parachute.

3. Gliders with low-landing speeds, carrying 15 troops, a Jeep, or a 75 mm Pack Howitzer are brought in. These gliders can land men and their equipment in small clearances with a relatively high degree of safety.

4. Engineer troops with special tractors and bulldozers are landed by glider and used to prepare an airstrip.

5. A special effort is made to establish satisfactory communications in the combat zones so that the troops already landed can be properly organized. Communications between the departure areas and the combat zones are also established, so that successive lifts of troops and supplies can be directed to drop in landing zones which are securely held.

6. Supplies are dropped by parachute or brought in with more gliders. Initial resupply, consisting chiefly of ammunition, has thus far been accomplished by using strategic bombardment aircraft and parachute delivery. If a landing strip becomes available and is securely held, transport aircraft are used for air landing of further lifts of men, equipment, fuel, and ammunition.

7. Airborne forces are landed forward of ground troops so they can be relieved in a few days. A turn-for-the-worse in weather conditions after an airborne operation has been launched can jeopardize the success of the whole venture.

8. Losses among the airborne troops during night operations are due mostly to landing crashes and accidents. Losses during daylight operations are due mostly to highly mobile enemy ack-ack installations.

9. Some attempts are made to retrieve gliders after the airborne operation is complete. The gliders are towed away by transports which are air-landing supplies if a suitable airstrip is available. Otherwise, special "pick-up" airplanes are used, but operations with these in combat zones have not been very successful so far. The pick-up airplanes cannot operate safely until the enemy has been subdued and driven back. By the time the enemy is beaten, a large portion of the gliders is generally not worth retrieving, or is not capable of being retrieved without extensive repairs.

The development of airborne operations during the current war has been bold and aggressive, but it has been soundly kept within the limits and capabilities of aircraft and equipment available for these operations. All major airborne operations have been carried out against Germany, a strong and well-organized enemy. Troop-carrier trains and airborne troops, as we know them now, are extremely vulnerable to all kinds of enemy fire, including small arms fire; hence, the requirement for local air superiority. Local air superiority against Germany far behind enemy lines would have been too costly, if not impossible; hence, the development that airborne forces be used to jump ahead of the main ground forces no more than 50 miles or so. The load carrying capacities of aircraft and gliders which were available for airborne operations placed immediate limits on sizes and types of artillery, vehicles, and equipment which could be carried into combat. This meant that airborne forces could not strike an effective blow against normally equipped enemy ground units. Further, supply by air was complicated by the fact that most of the aircraft available were former airliners, difficult to load and unload rapidly. Because of these two facts, airborne forces have been used only if they could be relieved by ground force units in about three days. At the present time, techniques and equipment which will permit large numbers of aircraft to fly to a pin-point target in enemy territory, unload rapidly and return, all under conditions of poor visibility, are still under development; hence the requirement for good weather conditions and the preference for daylight operations. By examining a specific airborne operation, we can see some of these limiting factors at work.

OPERATION "MARKET" — THE AIR INVASION OF HOLLAND

A general, graphic portrayal of this operation appears in Fig. 1. The factual data was gleaned from official reports on this operation and the figures given are approximate but substantially accurate.

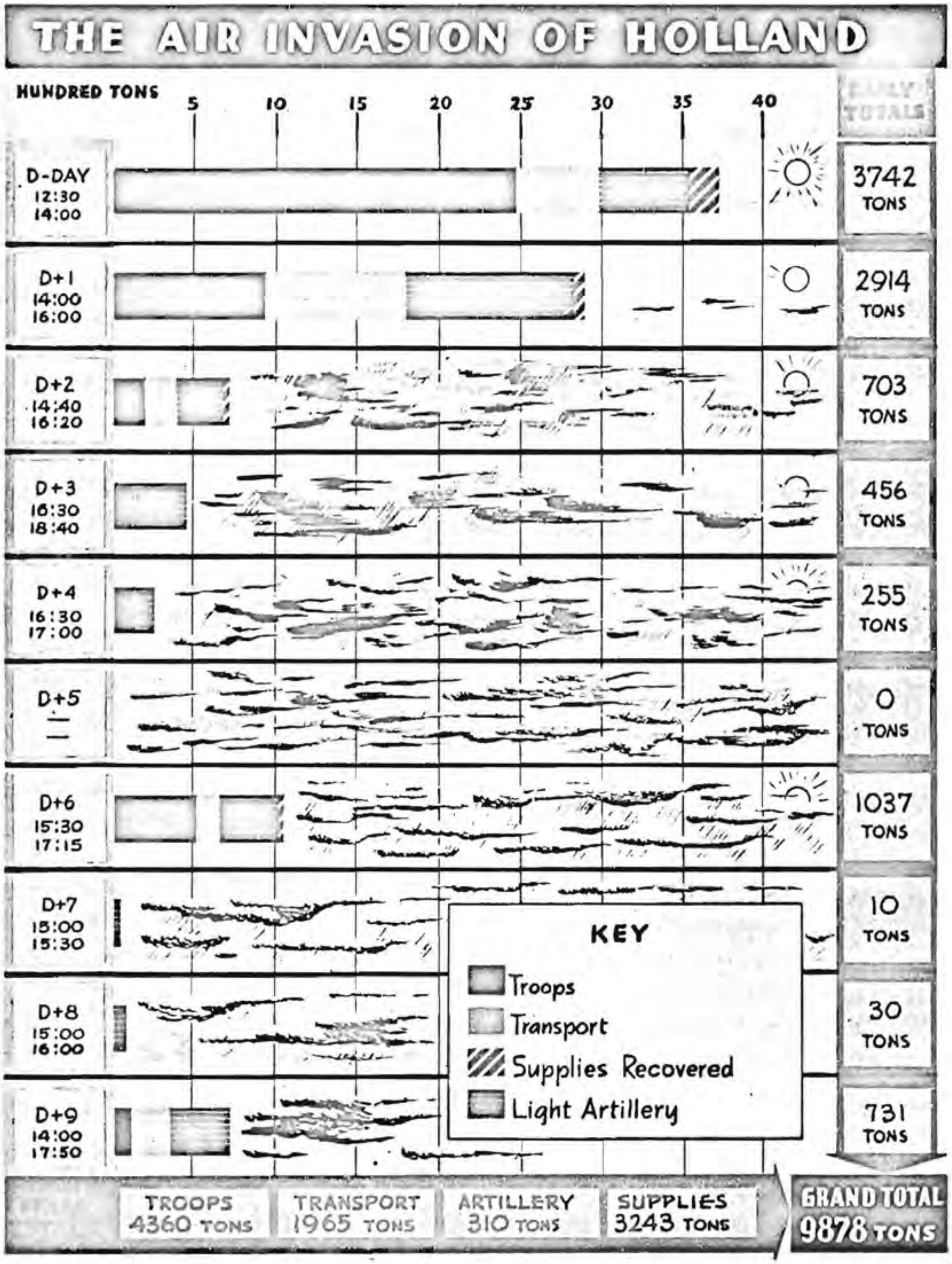


Figure 1 — Operation MARKET

This airborne operation was a brilliant success. A Polish paratrooper brigade and three airborne divisions, the American 82nd and 101st and the British 1st, were used to strike approximately 50 miles into enemy-held territory. At the point of deepest penetration the 1st British Airborne Division held out until the noon of D + 3 days, 24 hours later than the time set for the arrival of ground units of the British 2nd Army. Being the largest operation of its kind in history, MARKET demonstrated conclusively that the idea of airborne operations is sound; but, it also pointed out those technical and organizational problems which must be solved in the future. A discussion of some of these problems follows.

1. *The Weather.*

An airborne operation must start with the strongest possible initial troop delivery and it must be supported by the most rapid possible build up in men, equipment, and supplies. In Operation MARKET, it was possible to follow this principle successfully on D-Day and on D + 1, during which time about two-thirds of the force was delivered. But on D + 2 the weather became bad and the delivery of the last one-third of the force took place over a period of about eight days. While bad weather kept Allied aircraft grounded at their bases in England, the enemy had time to marshal his forces and build up stiff opposition against the airborne assault. He was also able to whittle down the troops which had already been landed, and to prepare himself for further landings which he knew would come as soon as the weather cleared. This meant a complete loss of the element of surprise for successive lifts, and a considerable reduction in the ability of the 1st Allied Airborne Army to strike effectively against the enemy while he was still weak.

A vigorous and effective program for defeating the weather is under way in the Army Air Forces. There is constant coordination so that the new discoveries and techniques evolved in the search for an all-weather air force are immediately applied to troop carrier operations. Airborne operations will be completely successful when it is possible to take-off and fly long columns of troop carrier aircraft, have them make safe deliveries of their cargo in enemy-held territory with pin-point accuracy, and then return safely to their bases, even under conditions of extremely poor visibility. In this connection, the problem of locating drop zones and landing zones in enemy territory, with as little reliance as possible on pathfinder activities, must be given special attention. It should be eventually possible to navigate directly to DZ's and LZ's, using only radio and radar equipment carried in the airplane and located in friendly territory.

2. *Lack of Firepower and Mobility.*

The artillery and transport used in this Operation consisted chiefly of the 75-mm Pack Howitzers and 1/4-ton trucks (Jeeps). (See p 21, "Composition, Limitations, and Growth of Airborne Units," for a detailed breakdown.) Airborne units must be equipped with heavier artillery if they are to match the firepower of normally equipped enemy ground forces. The lack of firepower means a lack of independence, because the airborne unit can easily be driven back. Further, aside from the obvious limitations in size and capacity, the number of Jeeps used in Operation MARKET amounted to only about one-third as much transportation per man as is available in a standard (triangular) infantry division. This means a lack of mobility. In Operation MARKET there were many instances where brilliant strategy and courageous fighting brought success against a superior enemy. But the fact remains that the airborne divisions were at a decided disadvantage when engaged by normally equipped enemy units.

3. *Supply by Air.*

It will be noted that a total of approximately 3250 tons of supplies were delivered by air during the course of this operation. This figure covers supplies delivered by glider, parachute, and by air landing, but includes only the total amount actually recovered by Allied troops. The recovery rate was rather low, since a total of about 5200 tons of supplies were dispatched. This means a recovery rate of about 63 percent for the operation as a whole. In the case of the 1st British Airborne Division, where the perimeter of defense was very small, and it was necessary to rely heavily on parachute delivery, the recovery rate was estimated as only about 13 percent of the total supplies dropped. The remainder fell behind enemy lines.

These facts show that better equipment and new techniques must be developed to improve the accuracy of supply delivery by parachute. Of course, basically, it is unsound to plan missions which involve resupply of an airborne unit over any extended period of time by parachute. However, parachute resupply is frequently a last and only resort, an emergency method of supplying isolated units with a small perimeter of defense. That is what happened in the case of the 1st British units at Arnhem. The ground force timetable broke down, the units were isolated and cut off, parachute resupply was the only method available by which they could be kept fighting. For such critical instances where it is urgently needed, the delivery of supplies by parachute must be made more effective.

All of the glider towplanes used in this operation carried no cargo at all. This meant a total unused cargo capacity of approximately 5500 tons, about one and two-thirds times the total amount of supplies recovered. Yet, there was absolutely no practical way in which this cargo space could be put to use. Had the glider towplanes been loaded with parachute-delivery containers full of supplies, and had an attempt been made to push supplies out of the doors of the C–47's by hand, the supplies would have been scattered over such a wide area that the greater part of the whole airborne force would have been needed to collect and assemble them. Recently, floor conveyor belts have been developed for rapid expelling of delivery containers through the door. Development work is being continued, and an overhead monorail system is being tested for possible use. These systems will mean a spread of about one mile at most in the drop of a planeload of supply containers instead of the five miles or so which can be expected if individual containers are pushed out of the door by men while the airplane flies a straight course. For example, the C-97 can drop 25,000 pounds of cargo in 20 seconds, in a length of about 4,000 feet, all movement of the cargo being fully automatic. The development of these systems for rapid dropping of cargo should be supplemented by the development of a suitable sighting mechanism for accurately spotting cargo released from low levels.

4. **Communications.**

The chart of Operation MARKET does not give any indication of the communications problems which were encountered. There was an almost total failure of wireless communication between Airborne Corps Headquarters and the 1st British Airborne Division. This prevented any control of the operations being carried out by that division, and the serious situation of the battle on their front was not known until about 48 hours too late; consequently, no orders could be sent to them in time to influence their action. Further, there was no effective communication between the oncoming airtrains (which had already left England) and the drop and landing zones in Holland. Thus, when a particular sector or section of a drop or landing zone was under heavy enemy fire, there was no method of advising the oncoming aircraft and landing gliders to avoid it. In addition, air support suffered to a certain extent because no contact was ever established with direct support aircraft. This was the first major airborne operation which was spread out over such great distances as to make unreasonably heavy demands on the communications equipment which was available to the airborne forces in the field at the time. This matter is discussed further in the section "Composition, Limitations, and Growth of Airborne Units", (cf. 21).

DOCTRINE FOR THE FUTURE

1. *The Practical Approach.*

Army Air Forces and Army Ground Forces are in agreement that future large-scale airborne operations should be considered as three-phase operations, as follows:

PHASE I. Seizure and Initial Occupation:

This phase constitutes the spearhead attack by airborne forces to capture an airhead, much the same as airborne forces are trained to operate today. Paratroops and assault gliders would be used. Chief requirement for this phase appears to be the development of a glider capable of carrying the 105-mm Howitzer and the 1-1/2 ton truck (prime mover) in separate loads. This development has been undertaken and it will permit the desired complete replacement of the 75-mm Pack Howitzer with the 105-mm weapon.

PHASE II. Immediate Reinforcement and Establishment of an Airhead:

This phase will of necessity follow closely the opening action. Reinforcement by infantry troops and mobile weapons is essential to secure and expand the airhead captured in Phase I. Construction of a landing area by engineer troops and equipment will be necessary. Aerial delivery of heavy equipment, up to and including the size, and weight characteristics of the 2-1/2-ton truck and the 155-mm Howitzer, is essential during this phase. It is considered necessary to have available heavy cargo gliders capable of carrying this heavy equipment. It would, of course, be more practical to use transport aircraft, if a landing strip exists. The CG-10A glider (towed by the C-46) and the XC-82 airplane, now becoming available, are capable of filling this need.

PHASE III. Reinforcement for Sustained Action and Exploitation of the Area:

During this phase it is assumed that we hold and defend an airhead into which heavy air transport can land. From this point on, we will seek to increase the ground mobility and striking force of the deployed units by augmentation with heavy trucks, armor, and equipment. These heavy items will fall into a weight and size category beyond the 2-1/2-ton truck and the 155-mm Howtizer. There is no aircraft, either in production or development, capable of performing this task.

The Army considers it necessary that all types of heavy equipment arrive at the airhead ready for immediate operation for Phases I and II. For Phase III, heavy equipment can be hauled as separate components, to be assembled after arrival at the airhead.

For future operations, a 750-mile radius of action is considered necessary for cargo aircraft. The cargo airplane, with its full load (including the case where a glider is in tow), should be capable of going a distance of 750 miles and returning to its base empty without refueling. It is planned that the entire operation would be supplied and maintained through air transport for an operational period of from 5 to 21 days.

This is indeed the practical approach to the problem: the gradual extension of present concepts as operational techniques are perfected and standardized, and as new aircraft with greater load-carrying capacities become available. But this practical approach visualizes the next war as a long war of attrition, fought along the same lines as the present conflict. This practical approach visualizes the use of airborne operations in the next war in much the same manner as now, but on a larger scale and with deeper penetration of enemy territory and longer period of action before relief by friendly ground troops. This is a sound line of reasoning. But we can judge present accomplishments and progress being made only by comparing them with the ideal.

2. *The Ideal Approach.*

Ideal principles for conducting future airborne operations can be postulated as follows:

a. Land a complete Airborne Army (or Air-transportable Task Force) at once any place in the enemy's territory in any kind of weather, at any time. (Local air superiority will still be necessary.)

b. Keep the force supplied, maintained and functioning, regardless of the nature or the duration of its task.

c. Evacuate the Airborne Army at a moment's notice, ready to fight, to another location.

These are rigid and demanding principles, perhaps all out of reason when compared to present attainments. Yet, only by striving for the perfect in the future can we improve present achievements.

Of course, there must be available to the armed services at all times those practical, simple implements and techniques for conducting airborne operations which have been tried and proven either in battle or in realistic maneuvers. The cargo aircraft, gliders, parachutes, etc., which have been tried in this war must be retained until new items developed prove themselves capable of performing the same job with greater efficiency and effectiveness.

However, our research program and our maneuvers during which we perfect operational techniques must be progressive: they must look to the future and be concerned with the new, which, though it be impractical today, will be commonplace tomorrow.

As the two greatest current disadvantages in the ground employment of airborne troops (namely, lack of firepower and poor ground mobility) are eliminated, airborne tactics must be reviewed and revised, particularly the doctrine of short penetration and quick support by other ground forces. With the independence gained by greater firepower and greater ground mobility, entire airborne armies can be employed deep in strategic areas of enemy territory. Such armies can be reinforced, supplied, and maintained entirely by air. This must be our aim and we must strive aggressively, with an open mind, for these ideals. If we do not, we can count on being subdued by a future adversary who will have done so.

FUTURE AIRBORNE OPERATIONS

1. *General.*

It is possible to discuss certain types of airborne operations which will be feasible as new aircraft and equipment, designed specifically for airborne work, become available. In doing this, some thought must be given to the extremely high cost (by modern standards and in terms of natural resources and man-hours) of large-scale air movements. It is true that cost is unimportant in war, and that taking an objective by more economical methods is not always practicable, if the cheaper method gives the enemy time to fortify and reinforce himself properly against the coming attack. However, airborne operations on a large scale can prove so costly that, conceivably, a nation could expend so much of its economic resources on an air blitz as to leave itself completely at the mercy of the enemy, if the air blitz failed. In spite of the high cost of large-scale airborne operations, we must do the development work and experimentation (including use of the equipment in maneuvers to get operational experience) on aircraft and equipment designed for this purpose. We must make ourselves fully aware of the capabilities and limitations of this type of warfare. Only by experimenting and constantly trying new things can we keep alive the "know-how" of conducting large-scale airborne operations and, at the same time, learn how to defend ourselves against them.

2. *Air Commando.*

Air Commando units are visualized as formidable forces which have been specially selected and trained, and are capable of fighting effectively in relatively small groups. They would be equipped with heavy firepower in terms of rocket-firing and recoilless weapons, demolition equipment, flame throwers and steel cutters, and the like. They can be best described as the future version of an "elite corps of parachutists."

Troops such as these could be used with great effectiveness against an inferior enemy, where complete air superiority could be quickly secured. There could be no question as to the success of the operation and the enemy would have to be weak enough so that the losses involved would not be prohibitive. These are the types of troops which could be used effectively to enforce an edict of a United Nations organization against a recalcitrant member. An airborne operation would be used to deny the enemy the time which he would need to mobilize his forces effectively and organize resistance. If he were not denied this time, a longer war and the expenditure of greater amounts of men and resources would be needed eventually to subdue him. The Air

Commando forces would capture key government leaders and the general staff, destroy lines of communications and transport, and create general chaos, making it possible for the friendly element in the enemy's territory to take over control of the country.

Air Commando units might also be used against extremely vital strategic targets in a war against a strong enemy. It can be expected that potential war-makers will attempt to move a good portion of their vital industries underground. The question of the relative effectiveness of carrying out repeated strategic bombing attacks over a long period of time or of using Air Commando units to do the complete job of destruction in one mission merits careful attention. An examination of the records to determine the total losses which we have taken in bombing some of the strategic targets and a comparison with the losses incurred in airborne operations might prove to be very useful. As industry is moved underground, strategic bombing may become so expensive as to be forced into the role of a disorganizing agent, the mission of total and final destruction of the target being accomplished by Air Commando units which would be landed immediately after a bombing raid. In the final analysis, the individual man will probably continue to be more effective than any machine man can invent, provided that we equip him with the proper weapons, place him close enough to the target, and protect him from enemy action while he performs his mission. The questions of possible enemy countermeasures and high losses among our troops, however, need to be carefully considered. The public can evidently bear to see the repeated loss of a relatively small number of our men over a long period of time in exchange for partial destruction of the target each time. But, if the losses in Air Commando operations could not be kept down, would the public be prepared to exchange the loss of a greater number of men in exchange for the complete and final destruction of a vital target? This matter must be carefully considered for it may well develop that effective damage (to the point where the enemy cannot quickly recover) against important strategic targets can be inflicted only by the combined use of strategic bombing and Air Commando units.

3. *Air Deployment of Ground Armies.*

a. Occupation and Reinforcement of Vital Outposts. In the event of a future war, immediate occupation and reinforcement of our vital outposts will be necessary. We must at all times be ready to take island bases at the outset, when war is threatened. Presuming that sufficient air power is available to retain local air superiority over these bases, the necessary ground force of men, guns, trucks, and equipment must be carried by air to the vital areas. The higher immediate cost of air transport is justified both by military necessity and by the saving of lives which might otherwise be lost retaking the bases.

In this connection, the question of range for future airborne operations has been considered. Two problems present themselves: first, the reinforcement of bases which are under our control so that we can count on having enough fuel reserves stored there to refuel aircraft for the return trip; second, the occupation of vital bases where United Nations or foreign control may prevent the storage of adequate gasoline reserves. At the present time, it appears that the aircraft required must possess a 2500-mile range for the first problem and a 2500-mile radius for the second problem, both with adequate reserves. This question must be reconsidered periodically, as the world political situation changes.

b. Support of Major and Important Ground Actions. In a long war of attrition, economical employment of the natural resources and manpower of a country becomes essential. Further, it can be expected that a long war of attrition would be fought only against a strong enemy with considerable airpower. Against such an enemy, it is difficult to conceive of gaining local air superiority (a prerequisite for successful airborne operations) deep in his strategic territory. Thus, until such time as the enemy's airpower can be gradually whittled down and overcome, airborne forces would be used only in support of major and important ground actions.

One possible type of airborne operation would consist of the air movement of standard ground force units from a port or point of embarkation to the action sector. The units would be deployed behind friendly lines, air transport merely being used to get them into action sooner. Future ground battles will probably be spread over wider areas, and extreme mobility such as can be afforded by air transport alone will be essential.

The second possible type of airborne operation would be similar to those we have seen in this war. Forces with greater striking power will be employed, and deeper penetration of the enemy's territory will be made. The duration of action before relief by friendly ground forces will depend, to a large extent, on the strength of enemy airpower and the resultant cost to us of giving air support in enemy territory to the airborne units. The characteristics of our airborne forces as planned for the immediate future (operation over a 750-mile radius and capability of sustained action for a period of about 21 days with supply and maintenance by air) are well suited for airborne operations of this second type.

4. *Study of a Possible Future Airborne Operation.*

This study was carried out primarily to get some idea as to the probable size of a future airborne operation (in terms of present-day equipment), in comparison with the major ones of this war and, secondarily, to stimulate thought and discussion on the development of aircraft and equipment for airborne operations.

A graphic picture of a possible future operation is presented in Fig. 2A. Three brigades of paratroopers, three standard infantry (triangular) divisions, and some corps support units are involved in this operation. The corps support units consist of an Antiaircraft Artillery Group, a Tank Battalion (Separate), and a Field Artillery Group. The three brigades of paratroopers are used to seize and hold the drop zones and landing zones. The three infantry divisions with about three days of supplies, are then completely deployed in a matter of about twelve hours. The corps support units and their supplies are landed on the morning of D + 1, completing the deployment of the whole force. Regular daily delivery of supplies then continues for the duration of the operation. A hypothetical operation of this magnitude would require aircraft with a total load-carrying capacity only three times as great as that which was available for Operation MARKET. However, the cruising speed of the aircraft and the ease with which they can be loaded and unloaded would have to be such as to permit two round trips in one day.

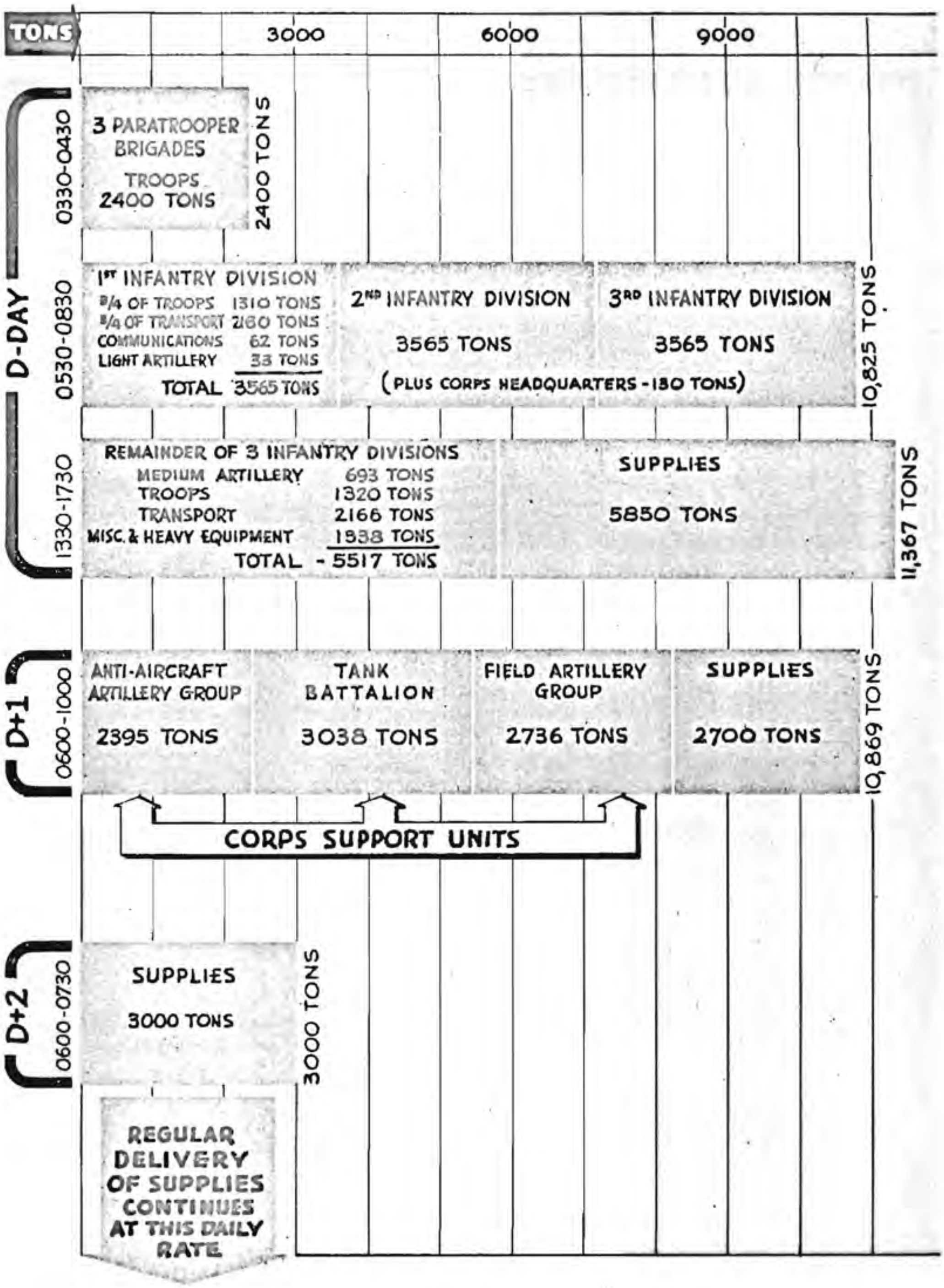


Figure 2-A — FUTURE AIRBORNE OPERATION — Three Paratrooper Brigades, Three Infantry Divisions, and Corps Support Units

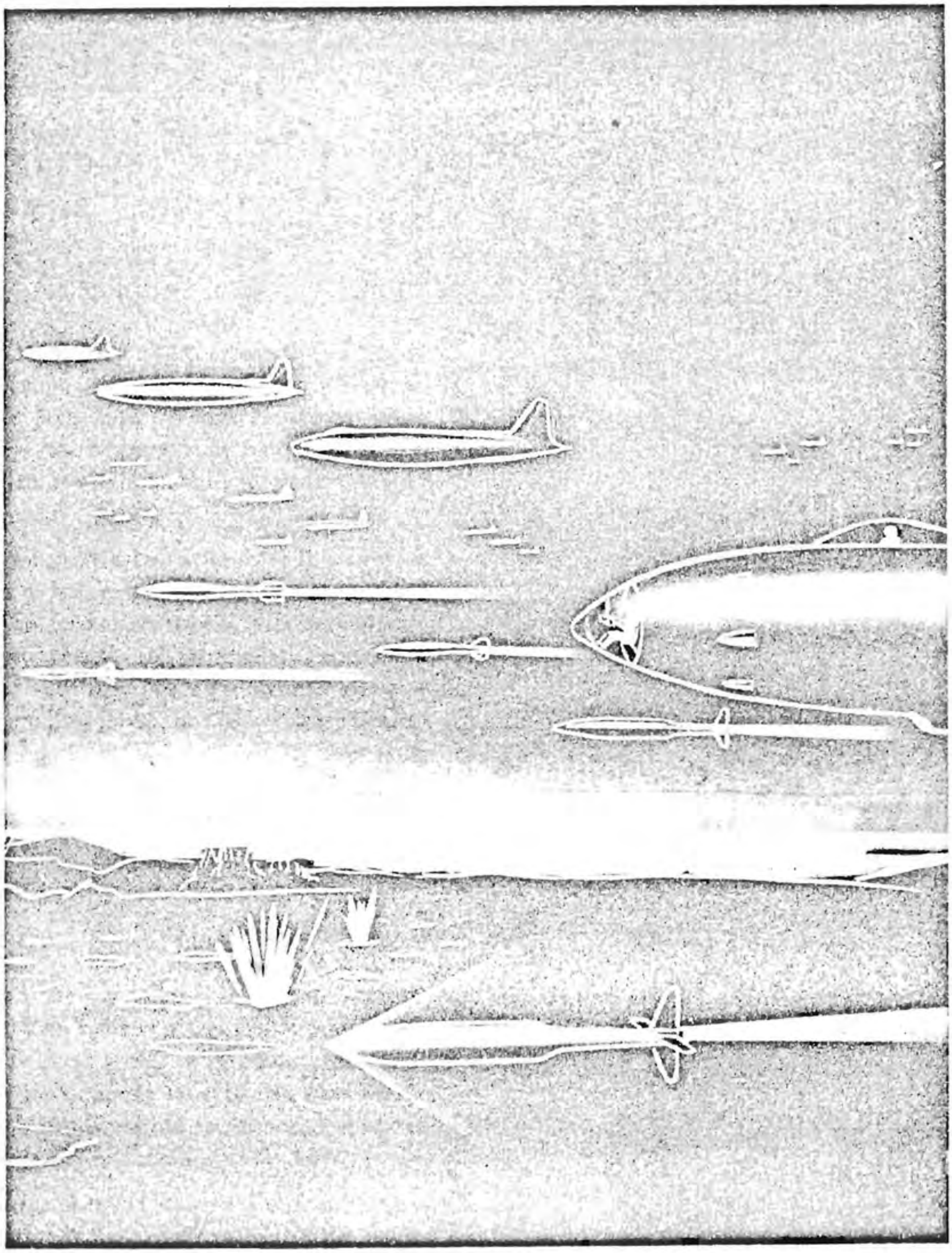


Figure 2-B — Bombardment

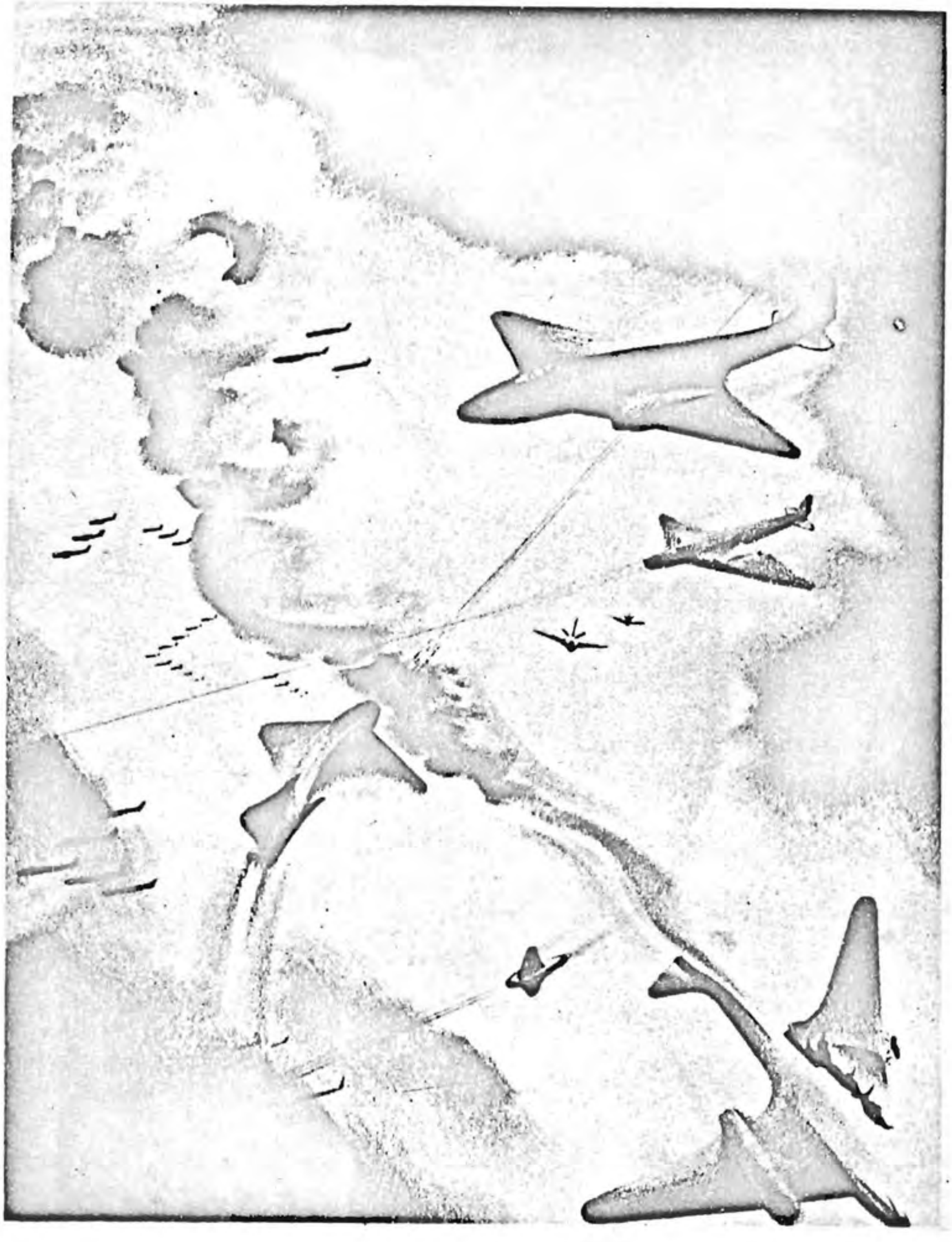


Figure 2-C — Air Superiority

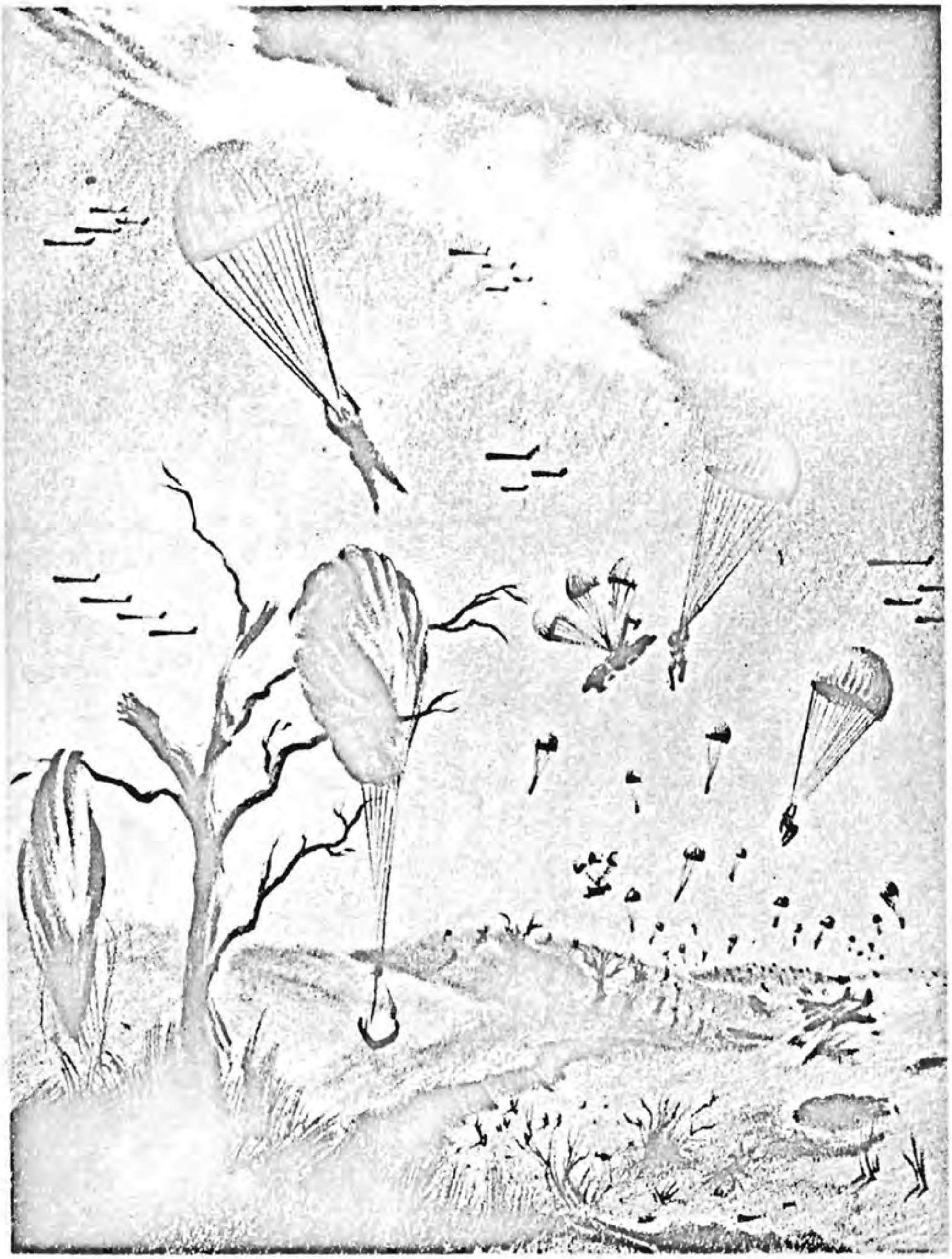


Figure 2-D — Attack

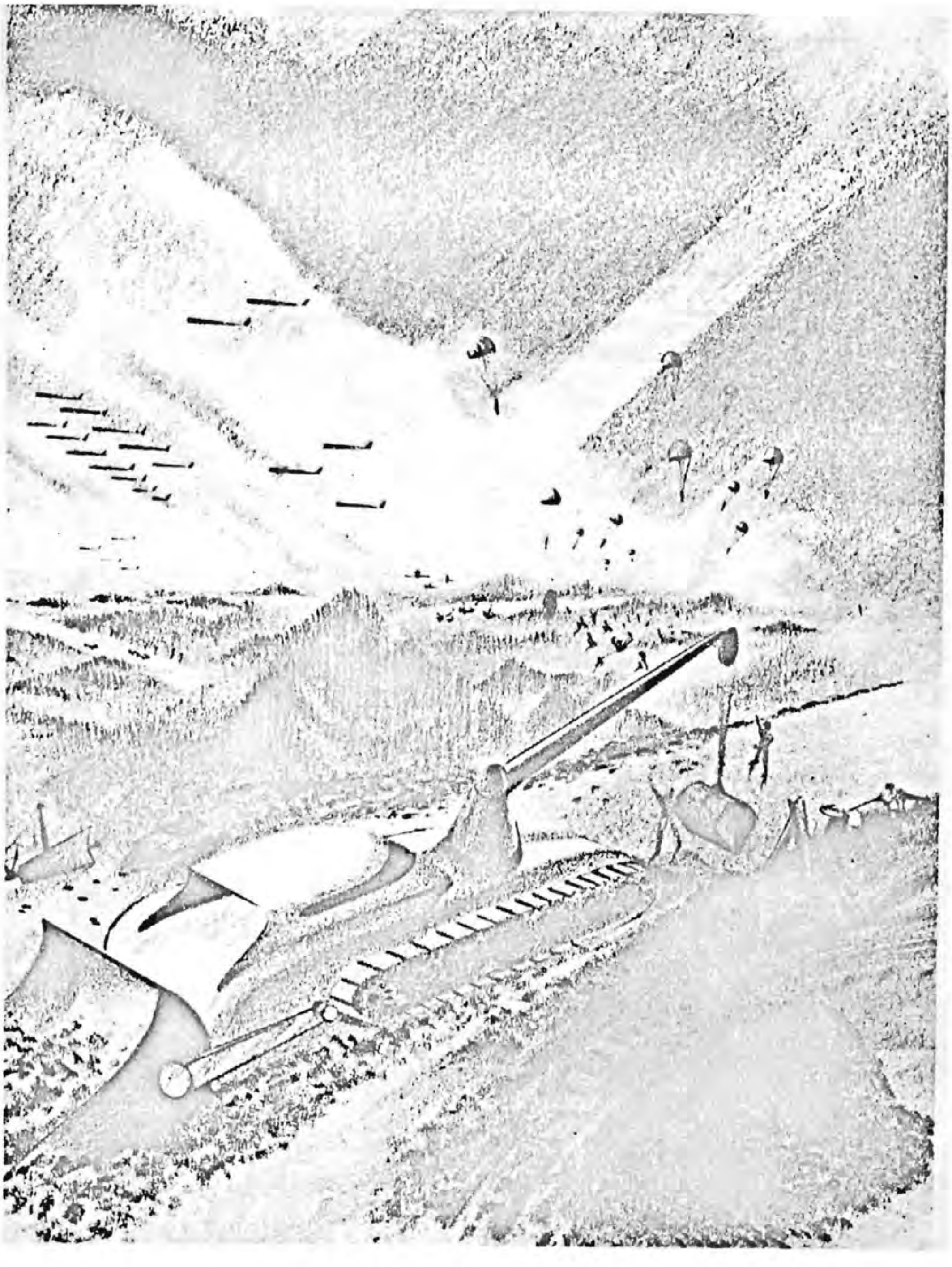


Figure 2-E — Landing Strips

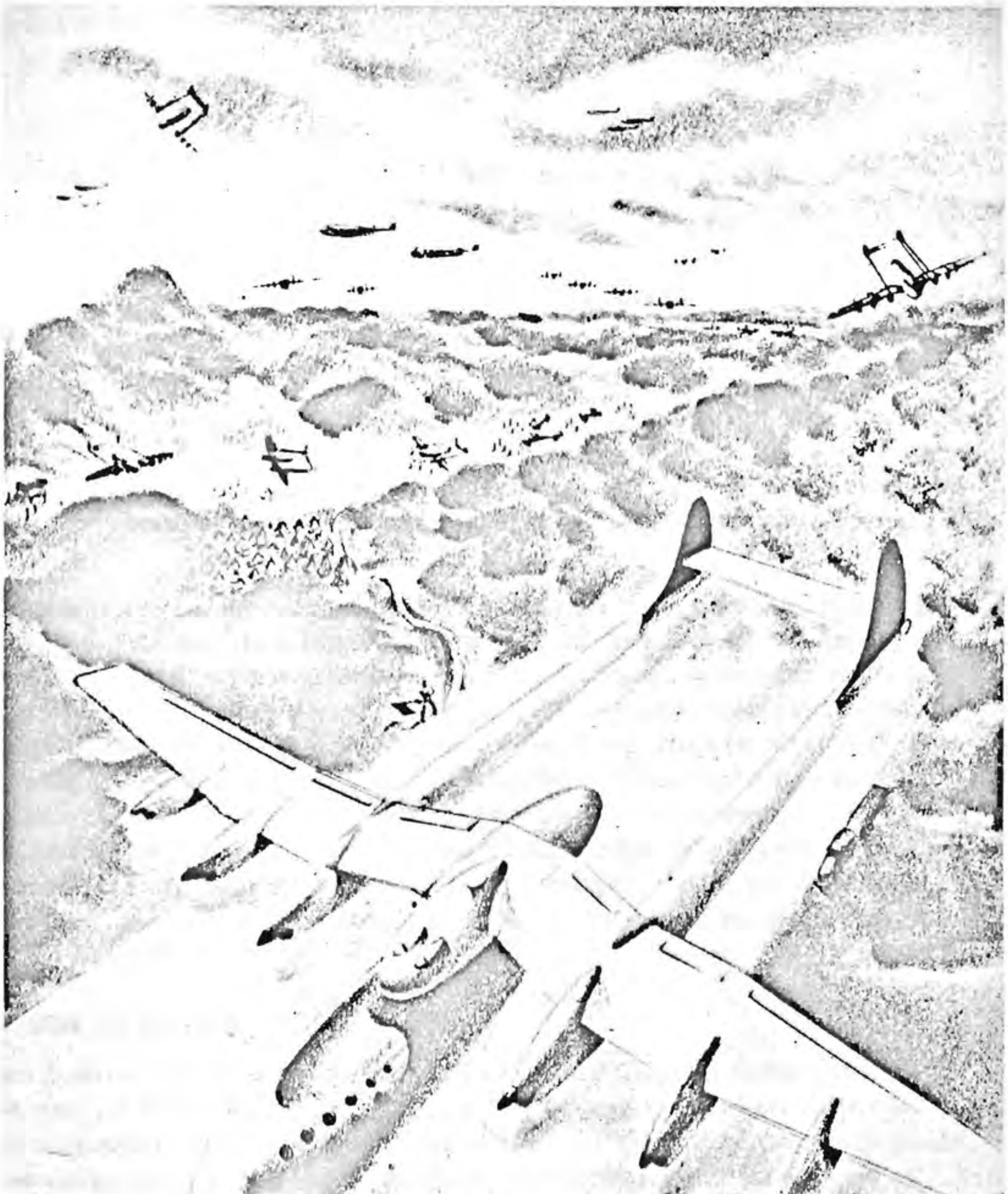


Figure 2-F — Supplies

Figs. 2B to 2F are a series of sketches, giving a futuristic conception of an airborne operation many years from now. Some of these sketches are based on studies of future aircraft made by the Design Branch (Aircraft Laboratory, Engineering Division) of the Air Technical Service Command.

COMPOSITION, LIMITATIONS, AND GROWTH OF AIRBORNE UNITS

GENERAL

The Airborne Division was first organized in October of 1942. It was then a 7500-(approximate) man organization, equipped with Jeeps as its means of transportation and 75-mm Pack Howitzers as its artillery. The Jeep and 75-mm Howitzer were chosen as transportation and artillery, respectively, not because they were best suited for combat, but because troop carrier aircraft then available could not carry larger items.

By September, 1944, the Airborne Division had grown considerably. It was now a 10,300- (approximate) man organization and a marked increase in amounts of transportation and artillery assigned to it had been made. However, this was a pure increase in size. The transportation which could be carried into combat still consisted of Jeeps and 75-mm Howitzers were still used as artillery. No new aircraft designs were available for use over those which were assigned in 1942, hence the same limitations still existed on size of equipment which could be carried. However, by this time, the new M3A1 105-mm Howitzer had been standardized. A new carriage had been designed for the old 105-mm Howitzer so that the weapon would pass through the doors of aircraft used by airborne troops. Twelve of these new weapons were used in Operation MARKET.

COMPARISON OF SIZE AND COMPOSITION

Figure 3 shows a graphic comparison between the Airborne Division in September, 1944, and the Infantry (triangular) Division. The figures given are approximate. Some difficulty was encountered in arriving at the total weights of communications equipment assigned to the various units. This is particularly true in the case of the airborne divisions used in Holland, since the communications setup was expanded somewhat immediately before the operation.

The airborne division was compared with the standard infantry division because it is assumed that airborne units will possess at least the firepower and mobility of the standard ground division in the future. Of course, it is very probable that the infantry division will undergo some reorganization after the war, and that new guns and equipment will be in use. However, the comparison merely serves to point out the disparity, in terms of present-day equipment, between what we already can carry by air, and what we would like to be able to carry by air.

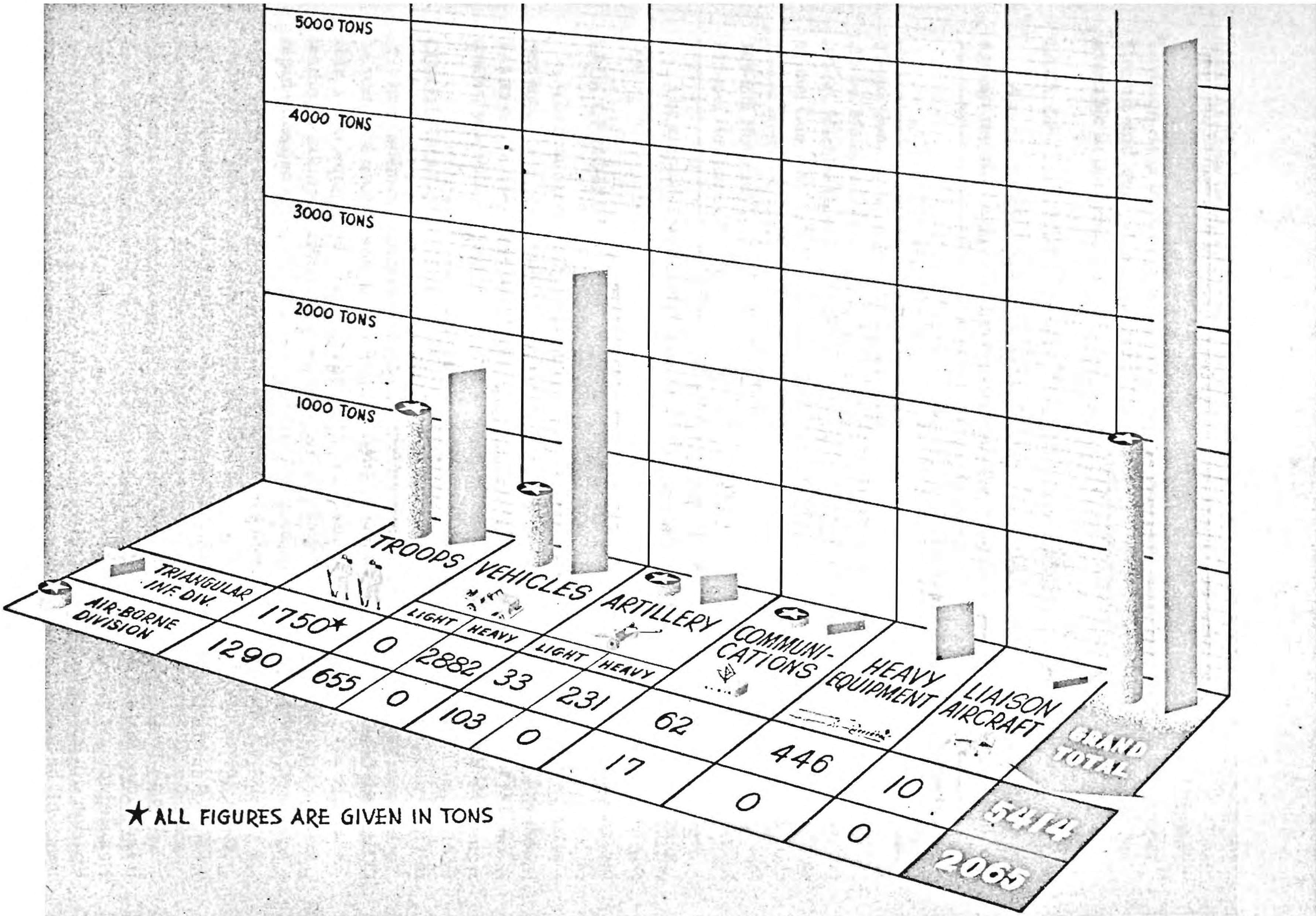


Figure 3 — Comparison between Standard Triangular Infantry Division and Airborne Division (1944)

LIMITATIONS OF AIRBORNE DIVISIONS

The comparison in Fig. 3 brings out some of the limitations of the Airborne Division. It is important to note that those limitations exist only because the proper aircraft and equipment, designed specifically for airborne operations, are not yet available in the field.

LACK OF FIREPOWER IN HEAVY WEAPONS AND ARTILLERY

A more detailed list of the artillery assigned to the divisions used in Holland as against the allowances for the standard infantry division appears as follows:

Heavy Weapons and Artillery	*Airborne Divisions Used in Holland*	*Infantry Division (Triangular)*
37-mm Gun..	40	—
.30-cal. Machine Gun................................	185	157
.50-cal. Machine Gun................................	92	236
57-mm Gun, AA......................................	—	57
75-mm Howitzer.....................................	40	—
105-mm Howitzer....................................	4	54
155-mm Howitzer....................................	—	12

The emphasis on heavier guns and artillery in the case of the Infantry Division is apparent.

LACK OF MOBILITY

Whereas the infantry division is equipped with about 1/5 T of transport vehicles per man, the airborne division at the present time has only about 1/16 T or less than 1/3 as much. The majority of vehicles in the Infantry Division are 2-1/2 T or 1-1/2 T trucks, whereas the Jeep (used in combat by airborne divisions) is a 1/4 T truck.

COMMUNICATIONS EQUIPMENT

In an airborne operation, the combat teams of an airborne division may sometimes be scattered over an area whose magnitude exceeds the range capabilities of the available radio equipment. This means poor communications right after the airborne landing, making it difficult to establish the disposition of the division and execute rapid offensive action. Further, drop zones and landing zones may have to be altered after the first lift has landed, to suit the operations already in progress. This means a demand for good communications between the combat zones, the oncoming subsequent lifts which are already in the air and approaching the DZ's and LZ's, and the departure bases and airfields which may be several hundred miles away. Communications have to be provided between the combat zone and direct support aircraft. Relieving ground formations will require continued and up-to-date information from the airborne units fighting on the ground. The battle by the airborne forces must be controlled in the field as must any other battle. Some of these demands for adequate communications were not met satisfactorily by equipment which was available in the field at the time of the air invasion of Holland. However, equipment now available (or becoming available) to troop carrier organizations and to airborne divisions appears to be adequate. The development of air and ground communications equipment must be closely coordinated in the future, as it has been in the past, to insure that the equipment will be well integrated and capable of meeting the specialized demands of future, large-scale, airborne operations.

LIAISON AIRPLANES FOR RECONNAISSANCE

The standard infantry division has an allowance of ten liaison airplanes which can be used for reconnaissance work. The need for liaison aircraft is even greater in airborne divisions where the elements of the division are more widely scattered, and where the disposition of both friendly and enemy troops has to be ascertained after the action has been joined. There is need for the development of a special liaison airplane (providing the utmost in simplicity, ease of operation, and ability to operate in rough terrain) which can be taken along when an airborne division goes into action. The airplane should also be capable of operating over roads at moderate speeds, with wings folded.

FUTURE GROWTH OF AIRBORNE DIVISIONS

The future airborne division must be capable of sustained action of the same effectiveness as the ground division, and must be equipped and organized accordingly. It will probably differ from the standard division only in the matter of having attached to it a large parachute element. The paratroopers and airborne divisions of today will probably have their equals in a small group of elite assault forces, the Air Commandos, in the future. Other than that, there will be no special airborne units but, rather, the entire Army will most probably be air transportable and will be trained for deployment by air.

DEVELOPMENT OF AIRCRAFT FOR TROOP CARRIER OPERATIONS

GENERAL

It is the purpose of this section only to trace the trends in the development of important general characteristics of aircraft used in troop carrier operations. No attempt is made to discuss in detail the exact nature of future aircraft, since that is the subject of another report written by the AAF Scientific Advisory Group. Rather, those developments in troop carrier aircraft which would insure the greatest exploitation of the possibilities of future airborne operations are pointed out and emphasized.

AIRPLANES

We began the war by converting standard airliners for troop carrier operations. These aircraft obviously are ill-suited for this purpose. Their doors are too small to pass bulky equipment. Their loading platforms are too high off the ground and they are equipped with side-loading doors. These factors make all loading and unloading operations difficult and extremely time consuming. Furthermore, these early aircraft are equipped with conventional landing gears and are not suited for operation in unimproved, rough fields.

The development of the C-82 airplane was initiated with the limitations of converted airliners in mind. This airplane was designed primarily for troop carrier operations. It is equipped with wide, rear-loading doors, large enough to pass articles with cross-sectional areas equal to the cross-section of its cargo compartment. Direct loading, straight in or out, is possible; however, the loading platform is approximately four feet from the ground and it still is necessary to use long, heavy ramps for loading and unloading operations. The airplane is equipped with a tricycle-type landing gear to make possible operation on hastily prepared landing strips.

The development of aircraft of the C-82 type naturally involves a loss in operating efficiency. For example, the C-54 airplane can deliver approximately 40% more cargo than the C-82 (over a 750-mile radius) in only about 75% of the time required by the C-82 (both airplanes using approximately the same amount of fuel for the job). This reduction in operating efficiency is outweighed by the great tactical advantages of rapid loading and unloading, and of being able to carry equipment in a fully assembled, ready-to-fight condition. The importance of this tactical advantage is emphasized when one considers that various ground force units are composed chiefly of large and heavy items of ordnance, transport, and armor. For example, the weight of these large and heavy items amounts to 65% of the total weight of a standard infantry division; 87% of the total weight of an antiaircraft artillery group; 90% of the total weight of a field artillery group; and 97% of the total weight of a tank battalion (separate).

Developments in the carrying capacity of cargo airplanes are shown in Figs. 4A and 4B. The useful loads shown in Fig. 4A are those which the various aircraft could carry when operating over a 750-mile radius.

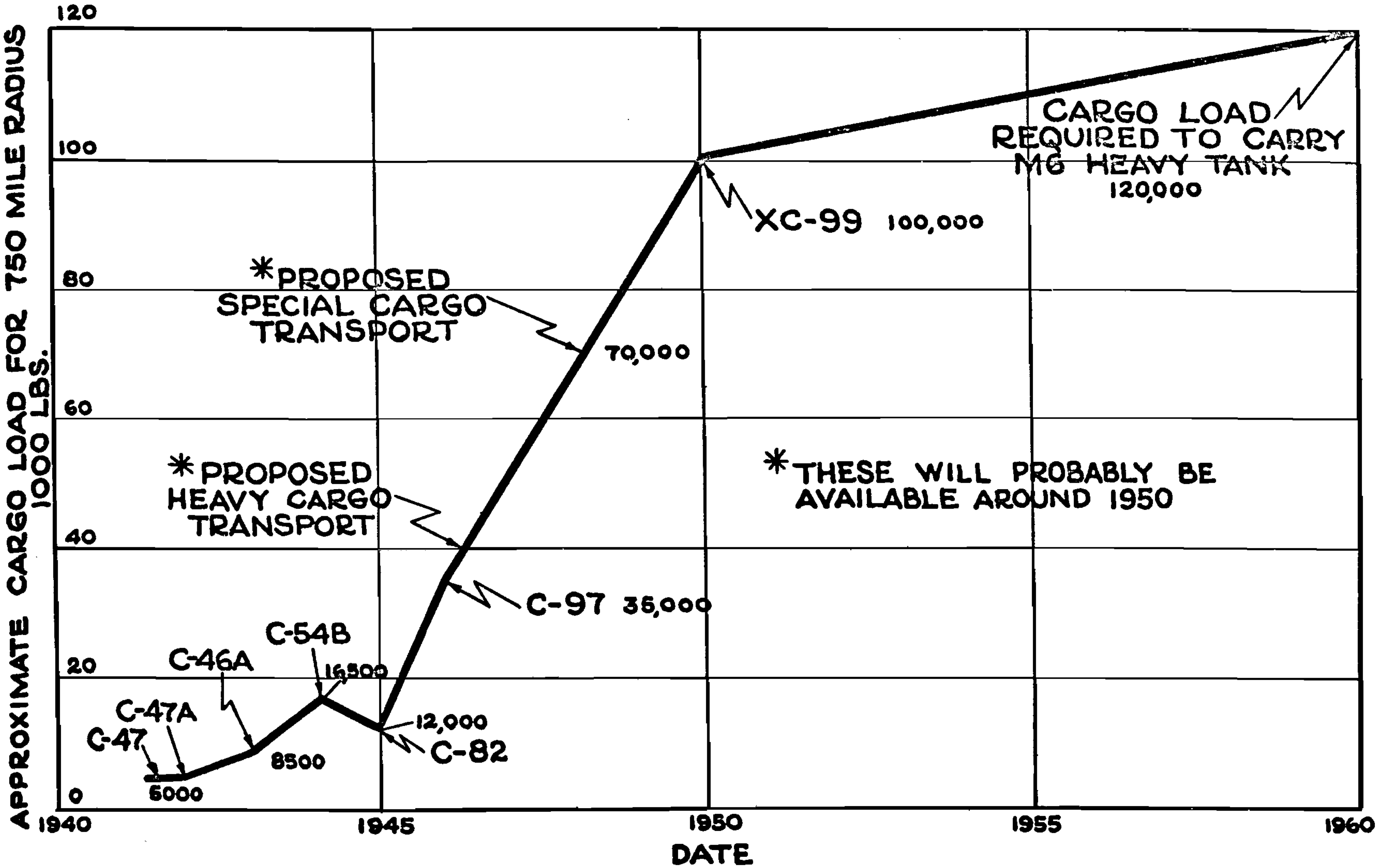


Figure 4-A — Carrying Capacity of Troop Carrier Airplanes

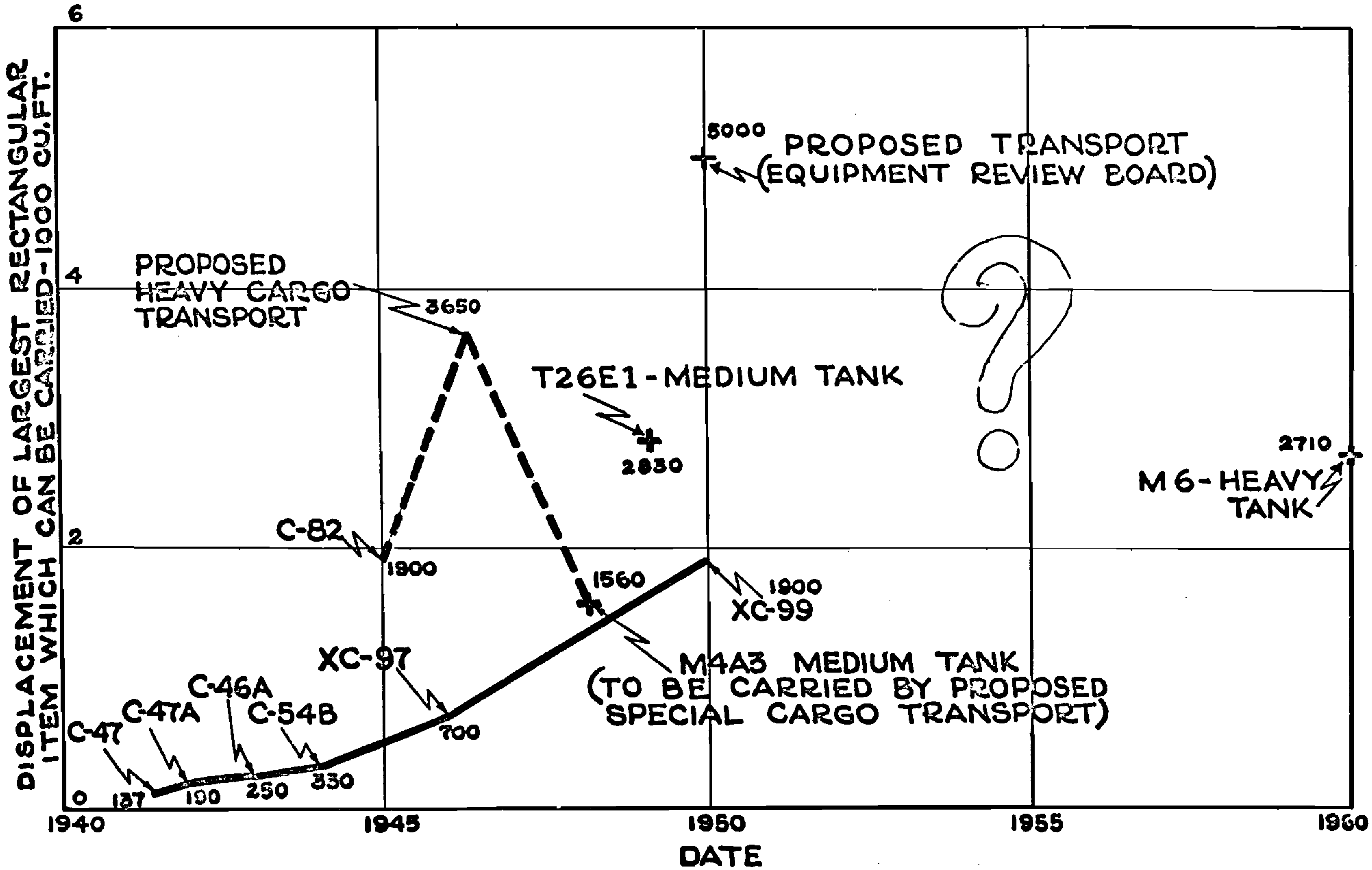


Figure 4-B — Carrying Capacity of Troop Carrier Airplanes

It is felt that aircraft should be developed with useful loads large enough to permit carrying items up to the heavy tank. At the present time it appears that the development program should include aircraft capable of operating efficiently over the following distances with adequate reserves: 750-mile radius, 2500-mile range; 2500-mile radius. A study should be made to determine whether or not three distinct groups of aircraft are necessary to operate efficiently over the distances stated; for example, the aircraft designed for operating over a 750-mile radius might be suitable for operations over a 2500-mile range, provided that the compromises which have to be made in operating efficiency are such that the development of two distinct groups of aircraft for these two missions could not be justified.

Fig. 4B shows the approximate volumetric displacement of the largest rectangular item of equipment which can be loaded in the various airplanes. The solid lines represent aircraft which have been designed primarily for airline operations. Long, heavy ramps are needed for loading heavy equipment into these airplanes and the loading operations are awkward and time consuming. The dotted lines represent the C-82 and two proposed troop carrier airplanes. The question mark indicates that considerable thought and study are needed to determine the optimum cargo compartment and door sizes on future troop carrier aircraft. For example, the proposed special cargo transport with a 70,000-lb useful load would require a cargo compartment with a displacement of only 1560 cu ft to carry the M4A3 medium tank; however it will probably have a total cargo compartment volume of approximately 7000 cu ft to carry a full load of troops (280 troops, 250 lb per man, 25 cu ft of cargo air space per man).

The following questions arise: (a) Should the doors on this airplane be large enough to permit carrying the larger but light items which the proposed heavy cargo transport (with the 40,000-lb cargo load) will carry? (b) Should the cargo load and door size of this airplane be increased to permit carrying the experimental medium tank now under development, the T26E1, which will weigh approximately 86,000 lb and require larger doors than the M4A3 tank? (c) Will tanks be carried in sufficient numbers to warrant the development of aircraft with special fuselages for this purpose to avoid the inefficiencies involved in carrying small but very heavy items in a very large cargo compartment?

These are questions which can be answered only if the dimensional and weight characteristics of all equipment in the United States Army are studied together, and the problem of moving the entire army by air considered. The need for an overall study of this problem is discussed more fully in the final section of this report.

Trends in the important performance characteristics of transport airplanes are shown in Figs. 5A and 5B. It is felt that future troop carrier airplanes which are designed for the early stages of an airborne operation should be capable of full-load take-offs and landings with ground runs not to exceed 1500 ft. (These aircraft are referred to as small airplanes in Figs. 5A and 5B.) The average pilot should be able to land these airplanes at speeds not over 60 mph. The larger cargo airplanes which might be used during the later stages of an airborne operation (large airplanes) should be capable of full-load take-offs and landings with ground runs of not over 3000 ft. Under emergency conditions it should be possible to make full-load landings

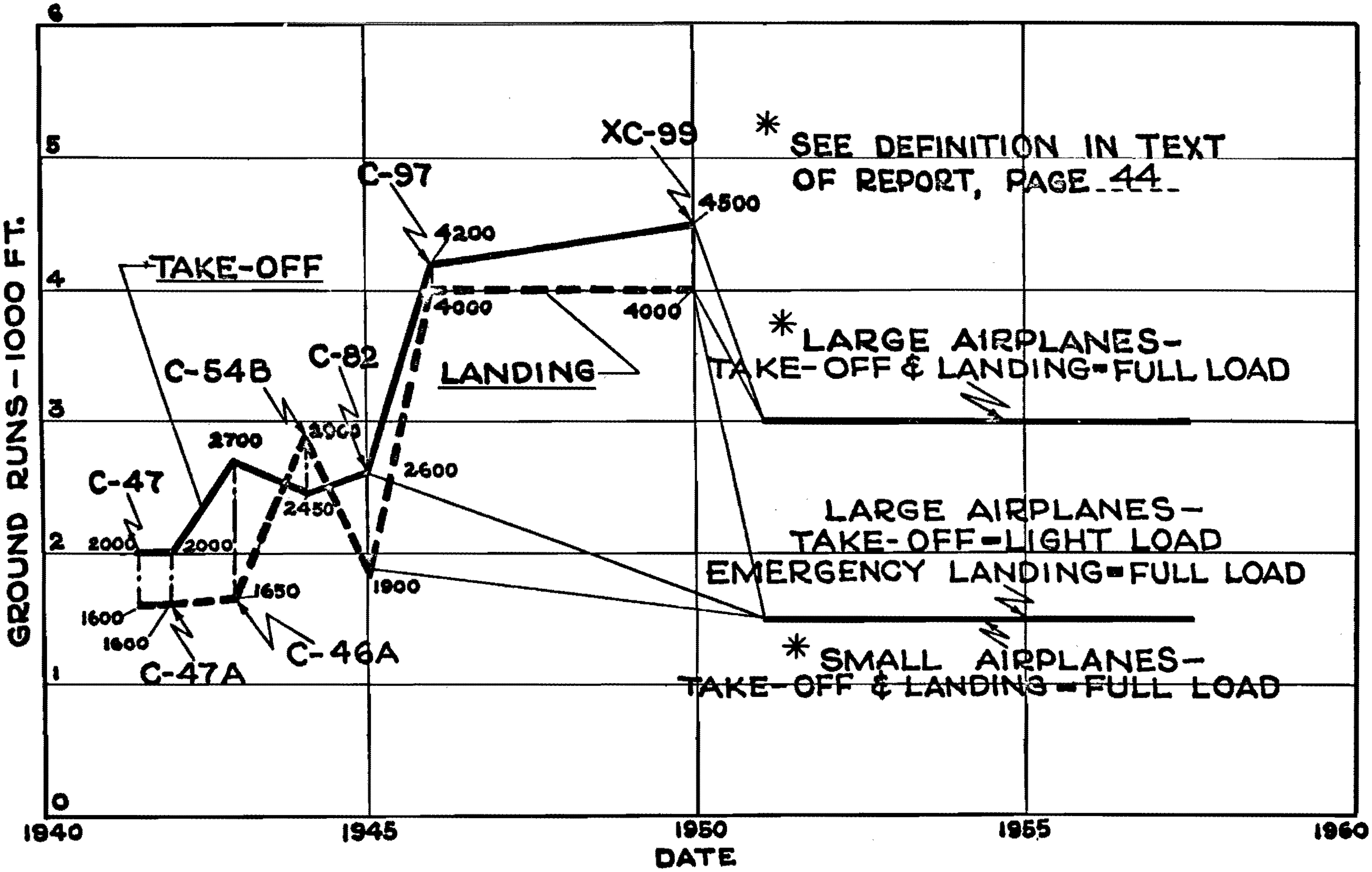


Figure 5-A — Performance Characteristics of Troop Carrier Airplanes

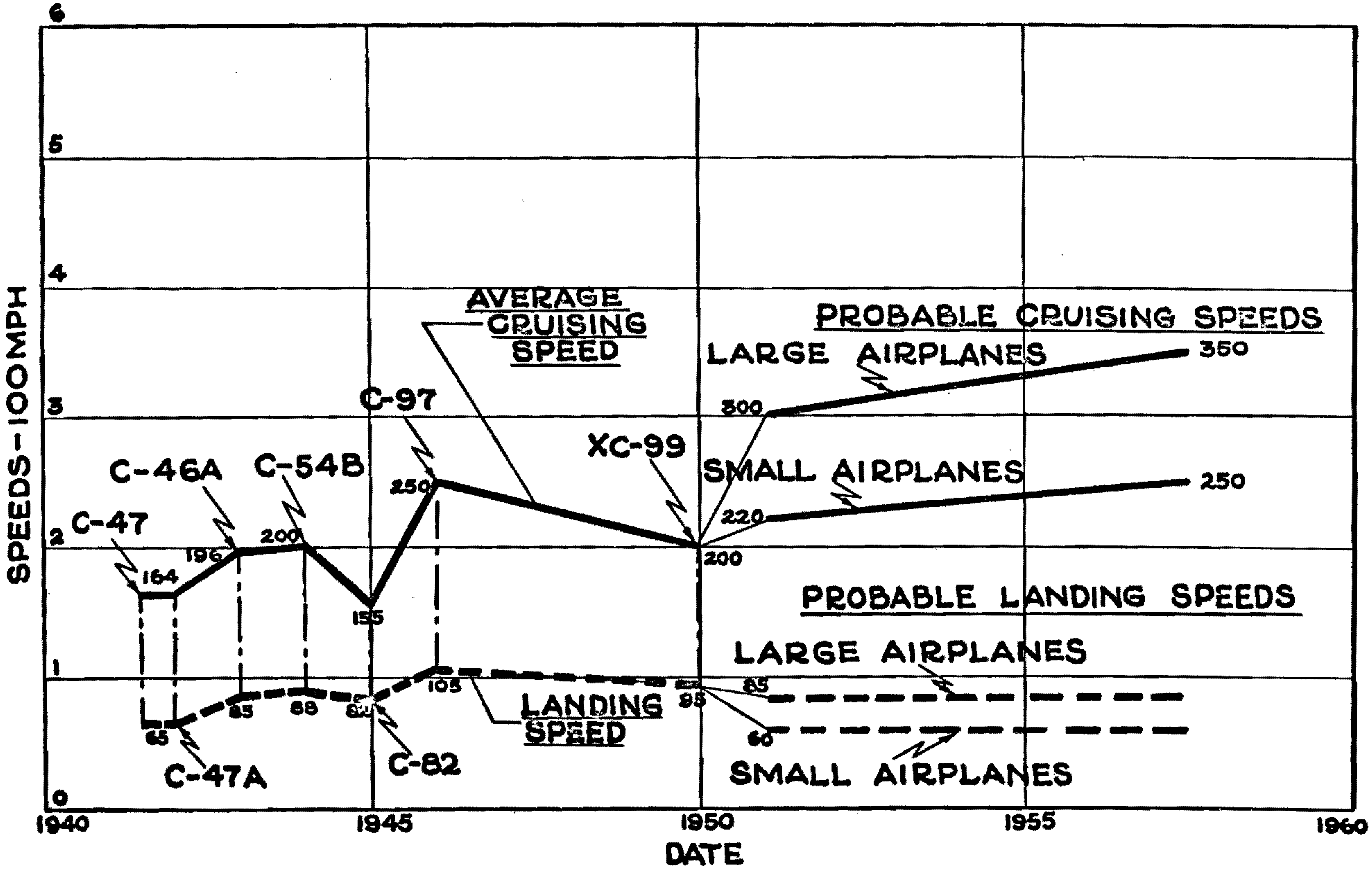


Figure 5-B — Performance Characteristics of Troop Carrier Airplanes

and light-load take-offs with ground runs of approximately 1500 ft. The landing speed should not be over 85 mph. For operations under normal peacetime conditions it is not necessary to meet these requirements; however, provisions should be made for the rapid installation of assisted take-off, deceleration, and boundary layer control devices so that these airplanes can make short take-offs and landings when they are committed for use in an airborne operation. Consideration should be given to the utilization of arresting gear, similar to that used on aircraft carriers, for decelerating large airplanes if other methods (rockets, reversible-pitch propellers, etc.) do not prove completely satisfactory. Mechanical high-lift devices and boundary-layer control should be used so that the low landing speeds can be obtained without compromising the high cruising speeds desired. Future troop carrier airplanes must be capable of operating in and out of comparatively small areas. (The term "small airplane" used here applied to all aircraft up to and including the airplane needed to take in the largest item of equipment of the standard infantry division. All others are "large airplanes.")

GLIDERS

The glider development program has had to hurdle many serious obstacles from its very beginning. Throughout the war a considerable difference of opinion has existed in the Army Air Forces as to the most desirable military characteristics and requirements for gliders. Gliders were first conceived as expendable, one-mission aircraft of cheap and simple construction, designed to glide quietly into enemy territory from high altitudes at night. This initial conception changed radically as experience in the use of gliders become available. Gliders now are towed to the immediate vicinity of the landing zones at altitudes of approximately 1000-2000 ft. They have to be able to withstand hard landings in rough fields without injury to occupants or damage to cargo carried. Far from being one-mission aircraft, gliders are retrieved, when possible, after a mission and used again. In training activities some gliders have been used for as many as 1200 flying hours.

Initial development and production programs for gliders were slow because of the necessary restriction that gliders would not be allowed to interfere with production of combat and training aircraft. Later, when glider production was accelerated to meet requirements for planned airborne operations, it became almost impossible to improve glider designs even when the troop carrier and airborne commands found that changes were necessary, as such changes would have interferred with the production program. Gliders have a lot of shortcomings; their cost is very high when compared to their short period of utility; they have to be crated and moved to combat zones by surface transport; very large airdromes are needed to mount a glider mission; a glider-towplane combination cannot take effective evasive action against enemy fire while in flight; and reliable instrument flight with a glider in tow has yet to be perfected. All of these factors have caused grave doubts as to the wisdom of using gliders at all. Thus, there have been delays in the initiation of production of new and larger gliders until such time as combat experience proved that they are worthwhile. In spite of all these hurdles, two good gliders have been developed by the AAF during the war. The Waco CG-4A glider and its successor, the CG-15A, can carry 15 men or alternate loads of a jeep or a 75-mm Pack Howitzer. It is widely acclaimed as the best glider used by anyone during the war. The Laister-Kauffman CG-10A can carry 42 troops or alternate loads of a 2-1/2-T 6 x 6 truck or a 155-mm Howitzer.

The glider now has proved itself as an effective combat machine. The development of gliders and glider techniques must be continued since, at the present time, this is the safest, cheapest, and most acceptable method of landing heavy guns and equipment during the assault phase of an airborne operation. New developments should stress the following: adequate crash protection for crew and cargo, low landing speeds, use of deceleration devices for shortening the length of landing ground roll, rapid unloading through wide rear-loading doors, adequate protection for pilot and copilot against small-arms fire, greater aerodynamic and structural efficiencies through the use of high-lift devices and metal construction, and the use of assisted take-off techniques for decreasing the length of take-off run required by glider-towplane combinations.

The two big lessons of this war in regard to gliders must be applied to the AAF glider development program. These lessons are, first, that the rigid demands of combat require the gliders to be full-fledged engineless aircraft, well designed, and constructed to insure that they will be capable of performing their missions; and second, that gliders (and glider units) can perform with maximum efficiency only if they are taken out of the "frozen-assets" category and some method found of making them perform a useful service during the long periods between airborne operations. The first lesson can be applied by promulgating a continuous glider program to insure that a sufficient period of time is allotted for designing new gliders and that up-to-date gliders are developed and ready for production at the beginning of an emergency. The second lesson demands that some of the major disadvantages of gliders be offset by coupling their development with the development of low-powered transports as discussed in the next section.

As new gliders are developed, the program of modifying troop carrier aircraft for glider towing should be continued. For every glider type, there should be available a suitable troop carrier airplane for towing the glider into action over a 750-mile radius. The development of special glider towplanes is not recommended. However, new gliders should be aerodynamically clean and their sizes should be so controlled that troop carrier airplanes in existence or under development can be satisfactorily used as towplanes; that is, each glider developed should be matched to a specific airplane which will be used as its towplane. Research should also be continued to make possible and practicable glider towing operations under conditions of zero visibility by developing automatic pilots for gliders and/or designing gliders which are stable in towed flight.

Figures 6A and 6B trace the development in load-carrying capacity of cargo gliders. Requirements for the proposed assault glider with an 8000-lb payload in a displacement of 1200 cu ft and for the proposed cargo glider with a 16,000-lb payload in a displacement of 1980 cu ft (later changed to 2400 cu ft) were stated by the AGF at a conference to determine the characteristics of these gliders. The development of an assault glider with 8000-lb payload in a displacement of 1000 cu ft and of cargo gliders with payloads up to 20,000 lb in a displacement of 3000

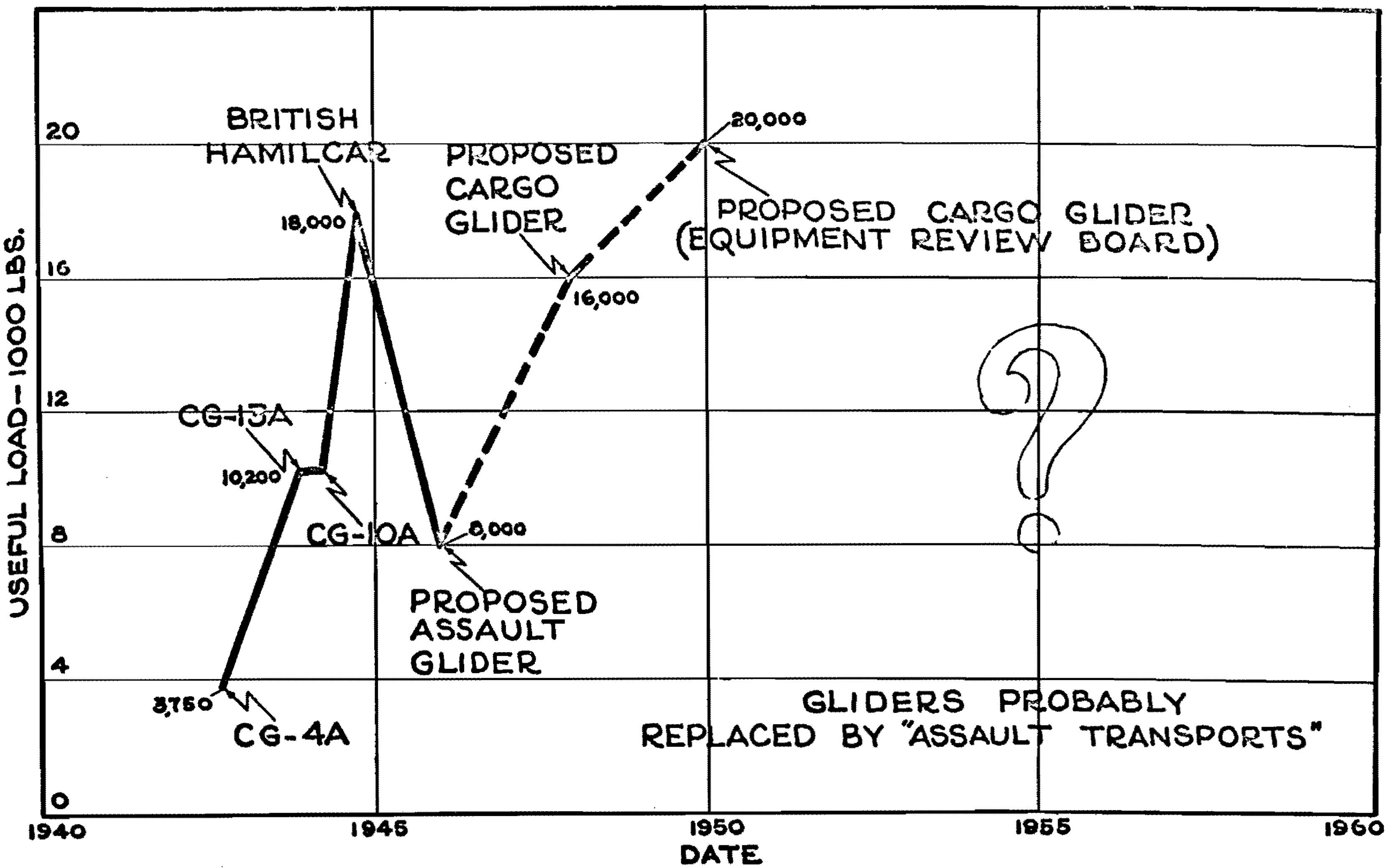


Figure 6-A — Carrying Capacity of Troop Carrier Gliders

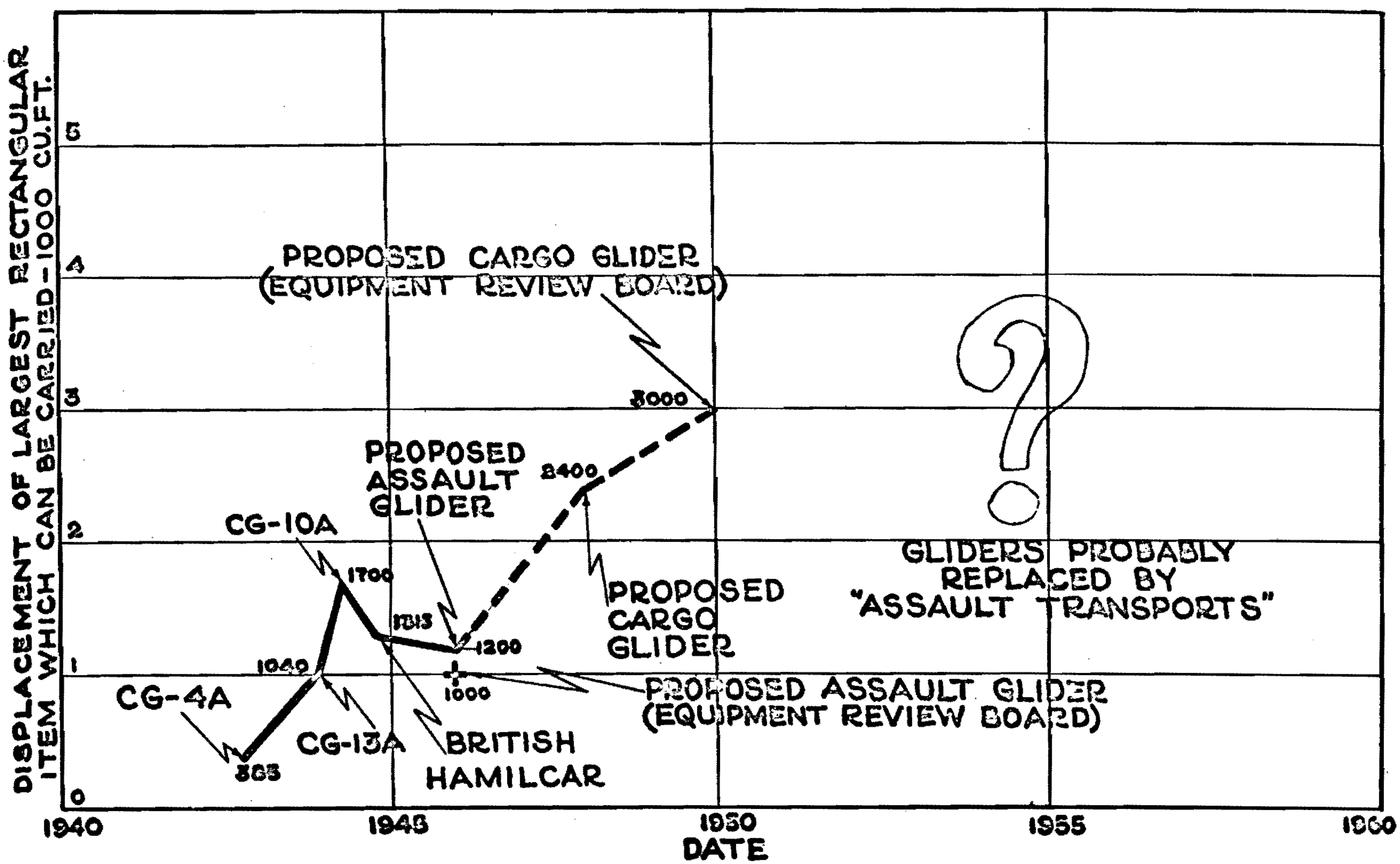


Figure 6-B — Carrying Capacity of Troop Carrier Gliders

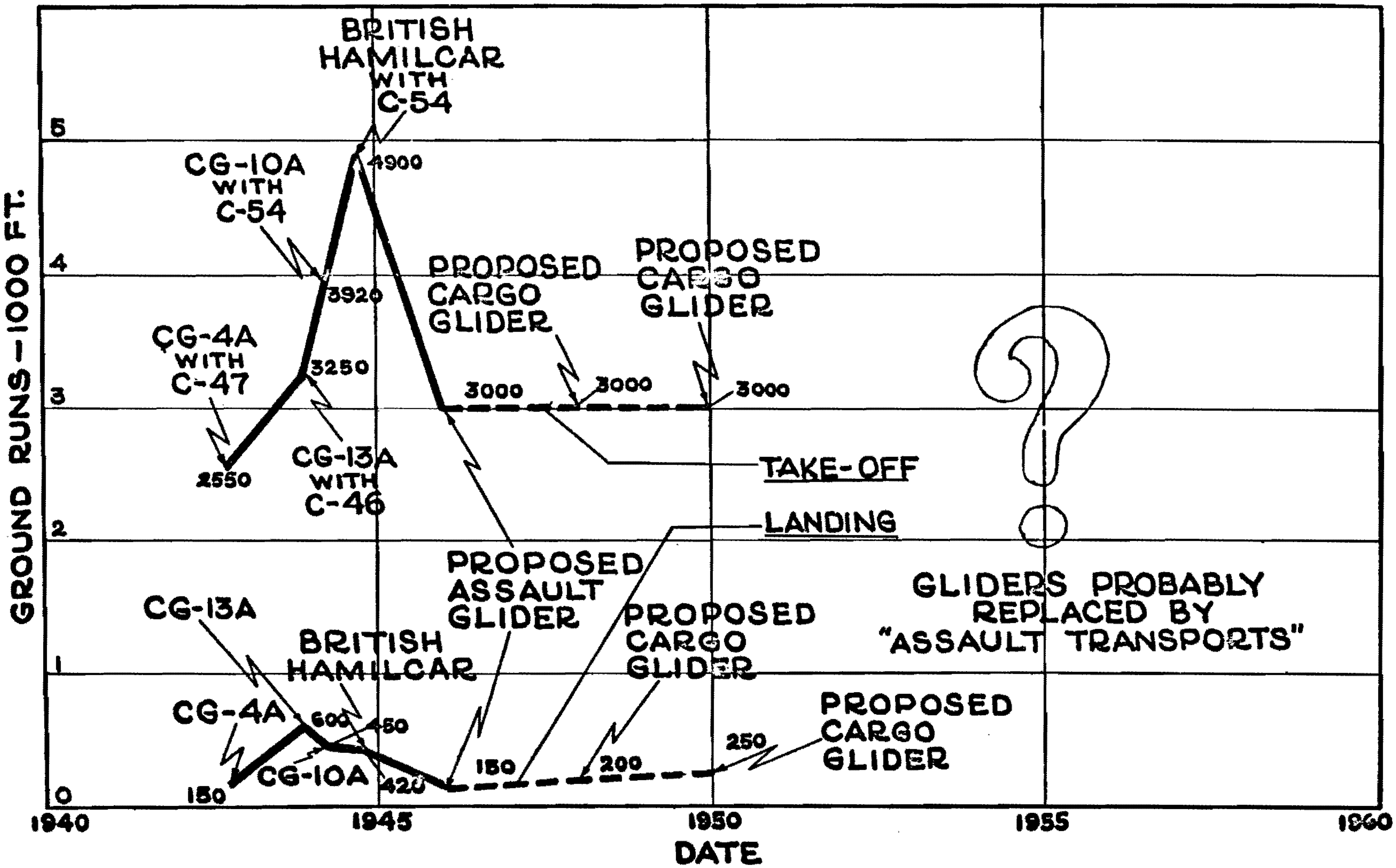


Figure 7-A — Performance Characteristics of Troop Carrier Gliders

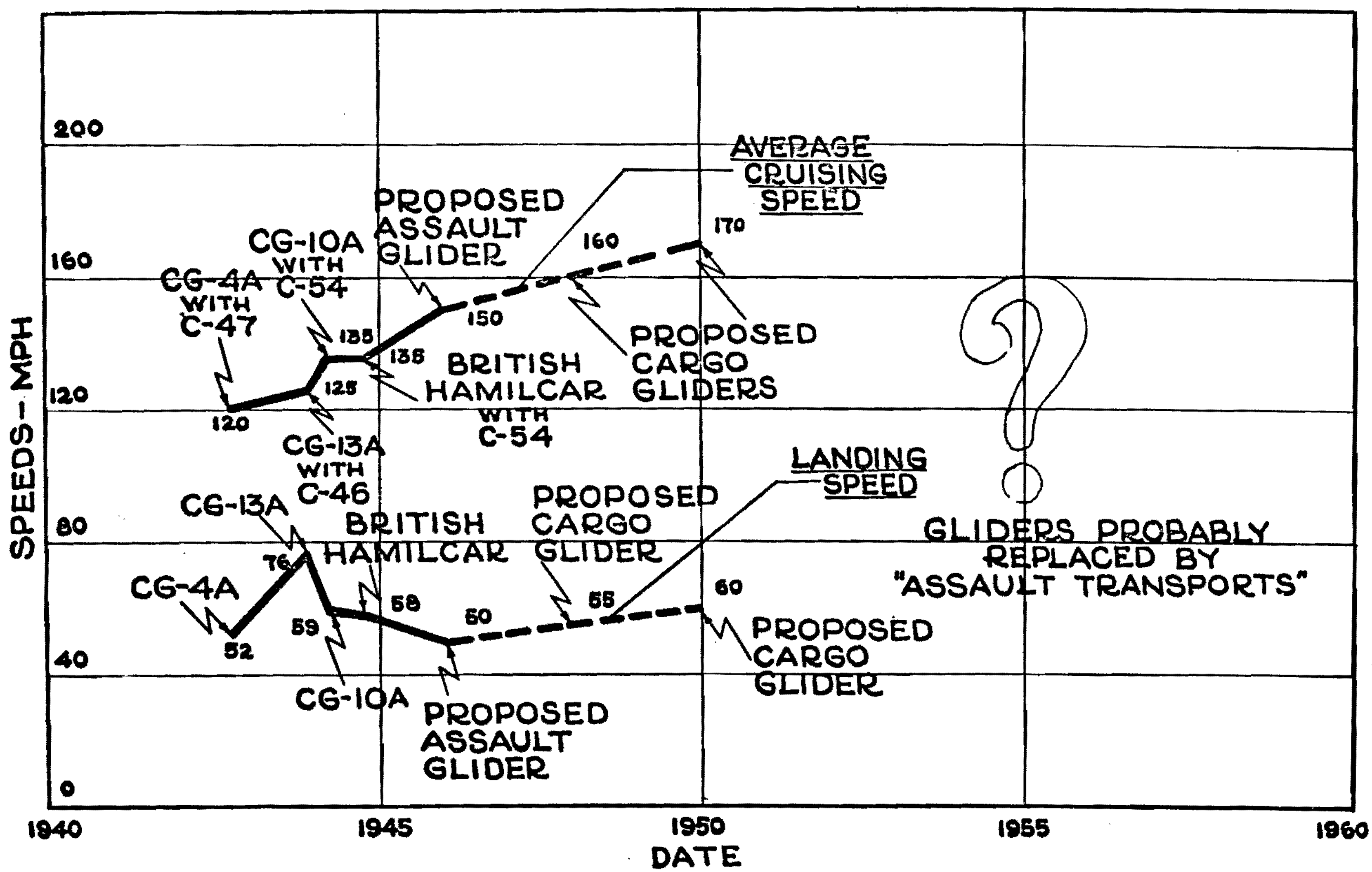


Figure 7-8 — Performance Characteristics of Troop Carrier Gliders cu ft was recommended in the preliminary study of the AGF Equipment Review Board. The question of load capacity and cargo compartment dimensions for future gliders should be given more thorough consideration. A complete study should be made of the dimensional and weight characteristics of all divisional combat and engineer equipment which would be needed during the initial stages of an airborne operation. Load capacities of future gliders should be increased only up to the point necessary to carry the largest item of divisional equipment which might be needed initially in an airborne operation before the time when it can be safely presumed that a suitable airstrip will be available for use.

The trends in important performance characteristics of gliders and glider-towplane combinations are shown in Figs. 7A and 7B. The take-off distances shown are for a fully loaded glider with the towplane loaded with sufficient fuel for operating over a 750-mile radius but with no cargo. Assisted take-off techniques should be utilized to permit all future towplane-glider combinations to take off with ground runs not to exceed 3000 ft. The landing speeds and landing runs shown for the proposed gliders should be considered as permissible maximums.

Figure 8 shows the progress which has been made in decreasing the landing roll of gliders. The landing run for the fully loaded CG-4A glider is shown when various deceleration devices are used. Rockets have not been accepted as a decelerating device because of their vulnerability to small-arms fire. The Chase plow has proven quite effective. It is a small plow, which is retracted beneath the fuselage of the glider on take-off and which can be extended so that it will drag through the ground when the glider makes a landing. (Experimental work is in progress at the present time in the use of undrawn nylon as a means of absorbing the kinetic energy of a rolling glider. The nylon is attached to an anchoring rod which is fired into the ground, from the glider, with a bazooka. Results are not yet available.) Decelerations of at least one g by means of devices of this nature should be possible on all future gliders.

LOW-POWERED TRANSPORTS AND ASSAULT TRANSPORTS

One of the more significant developments during the recent war has been the low-powered transport. The idea had its start with a suggestion that a "65-hp power package" be installed on the CG-4A glider. This power package would have carried a small engine with a propeller and a limited quantity of fuel and would have been capable of doubling the gliding range of the glider. Going one step further than this, XPG-1 "powered-glider" was developed. This was CG-4A with two 130-hp engines. The glider with this engine installation could be towed off the ground and part way to the objective in the normal manner. The engines would then be started and the glider would release from tow and complete the mission under its own power. The power available was sufficient to maintain level flight with a fully loaded glider, but not enough to allow the glider to take off by itself with a full load. However, when unloaded, the glider could just barely take off under its own power after a mission and be ferried back to its point of departure.

The power of engines which can be rapidly attached to gliders has been increased to the point where powered-gliders have become efficient low-powered transports for short hauls behind the lines where the following factors are an ad-

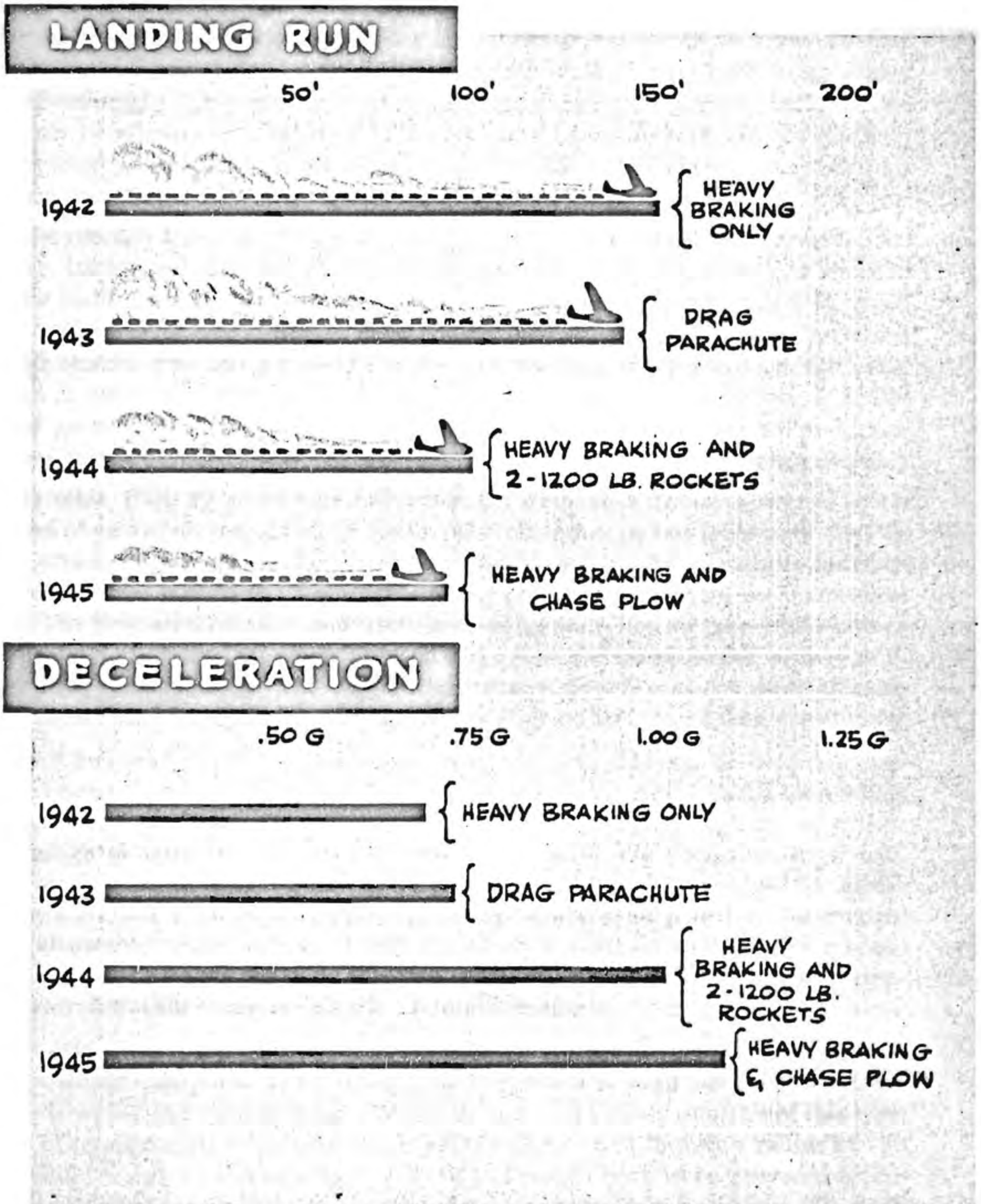


Figure 8 — CG-4A Glider Gross wt 7500 lb Landing Speed — 55 MPH

vantage; rapidity and ease of loading and unloading; the ability to handle bulky items of equipment and to operate from hastily prepared strips; and simplicity of maintenance and ease of operation. The advantages of having such a transport for short-haul work immediately behind the lines cannot be overemphasized. To date all low-powered transports have been gliders with the engine installation added as an afterthought. This involves certain structural and aerodynamic inefficiencies which can be eliminated if the engine installation is considered when the glider is first designed. With this in mind, future gliders should be designed from the start for rapid conversion to low-powered transports.

More recently it has been suggested that a special type of aircraft be developed for use as an assault weapon. The assault transport would be basically a cargo airplane with low landing speed (about 40 mph) but with comparatively high cruising speed (about 200 mph). It would be equipped with a landing gear suitable for operation on rough terrain. Provisions could be made for jettisoning the fuel tanks or for using gasoline in solid form to reduce the fire hazard during combat landings. ("Solid" cakes of gasoline which are not vulnerable to gunfire but which give off liquid gasoline when put under slight pressure have been successfully developed by the British.)

The table (Fig. 9) shows the important characteristics of low-powered transports and of an assault transport. Of the five aircraft shown in this table only the PG-2A has actually been built and flight tested. The figures for the remaining four aircraft are estimates taken from proposed military characteristics and from theoretical studies. The proposed medium and heavy powered-gliders are the powered versions of the proposed assault glider with 8000-lb cargo load and cargo glider with 16,000-lb useful load, respectively. The cargo compartment dimensions for these aircrafts are not shown since they are the same as for the gliders from which they are derived.

It will be noted that the low-powered transports probably will have certain limitations. The engines are added at the expense of reductions in the cargo load which can be carried as a glider. This means that although the cargo compartment will be large enough to carry certain items of ground equipment, the allowable cargo load will be too low to permit doing so as a transport. For example, the CG-10A glider can carry a 2-1/2-T 6 x 6 truck (11,000 lb) but a powered version of this glider would have an allowable cargo load of only approximately 6000 lb. Also the cruising speed and radius of action of the proposed transports are somewhat restricted when compared with desirable characteristics for future operations.

The assault transports would be designed to overcome the probable limitations of low-powered transports. Their cruising speeds would be high whereas their landing speeds would still be low. However, it will be noted that an airplane of this type, capable of transporting a cargo load of approximately 9000 lb over a radius of 750 miles, would weigh approximately 45,000 lb and would have to be powered by engines with a total normal rated power of approximately 5000 hp. (Two XR-4360 engines were assumed in the theoretical study for the assault transport shown in the table. The predicted performance for this aircraft could be made more optimistic if a higher wing loading had been used and the low landing speed obtained by the use of boundary layer control.) This is a large, expensive airplane and there is some question as to whether or not such an airplane would be tactically suitable for assault

Aircraft	PG-2A (Powered CG-4A)	Proposed Low-Powered Transport (Medium)	Proposed Powered CG-10A	Proposed Low-Powered Transport (Heavy)	Probable Assault Transport
Total Normal Rated Power of Engines	400	900	2,100	2,100	5,000
Gross Weight (lb)	9,000	15,000	29,500	30,000	45,000
Cargo Load (lb)	2,260	4,000	6,000	9,000	9,000
Take-off Ground Roll (ft)	2,200	1,000	1,100	1,400	450
Landing Ground Roll (ft)	800	250	1,000	500	150
Average Cruising Speed (mph)	75	140	145	145	200
Landing Speed (mph)	54	50	70	60	40
Radius with Maximum Cargo Load (miles)	220	400	425	350	750

Figure 9 — Characteristics of Low-Powered Transports and an Assault Transport

operations and whether or not the losses involved would be low enough to make the use of aircraft of this type more economical than the use of gliders. These same questions also exist in connection with the possible use of low-powered transports in the initial phases of an airborne operation.

It is interesting to note that a transport airplane of this nature, the Arado Ar. 232, was reported to be in service in the German Air Force at the end of the war. Its gross weight was reported as approximately 52,000 lb with a payload of approximately 20,000 lb. It is powered with four 9-cylinder radial engines. Boundary layer control equipment and special flaps are installed to insure low landing speeds and good aileron control at low speeds. A tricycle landing gear is provided; it is partially retracted immediately after landing, lowering the fuselage until ten pairs of small wheels attached to the belly come into operation. This results in high deceleration and makes possible landings in confined spaces. It also insures that the aircraft is close to the ground and in the most convenient attitude for loading and unloading when it comes to rest. The aircraft is reported to take off in less than 600 ft, presumably with light load. Armor plate is provided for pilot and copilot and seven machine guns are mounted on the aircraft.

Both low-powered transports and assault transports would do away with many of the great disadvantages of a glider-towplane combination. The large airports and large overhead of personnel and equipment required to launch a glider mission would be eliminated; the transports could operate in any kind of weather and from small unimproved fields; they would be useful between airborne operations as cargo planes; they could be easily ferried to combat theaters; they would be maneuverable while on a combat mission; and they could make safe landings in fields not much larger than those required for gliders.

It is strongly recommended that both gliders convertible into low-powered transports and assault transports be developed and procured in sufficient quantity to permit evaluation of their tactical suitability in actual maneuvers (or combat).

THE USE OF PARACHUTES AND DECELERATING ROCKETS FOR DROPPING HEAVY EQUIPMENT

This system has been proposed and tried experimentally with some success by the British. It involves carrying in heavy bombers all items of equipment needed during the assault phase of an airborne operation and dropping them by means of parachutes and rockets. The equipment would be dropped with zero forward velocity and zero ground roll. Hence there would be no terrain problem to be considered in connection with the choice of suitable drop zones for an airborne operation. This method also would be ideally suited for night operations.

A series of sketches showing the sequence of events in this system appears in Fig. 10. Parachutes are used to decelerate to a certain predetermined terminal velocity the item being dropped. When this terminal velocity and the nearly vertical part of the trajectory of the falling item are reached, a plummet is unreeled which houses a special switch for firing the rockets. When the plummet strikes the ground the rockets are fired. They decelerate the load and allow it to come to rest at ground level. In the sketches the rockets are shown mounted on the sides of the jeep. This

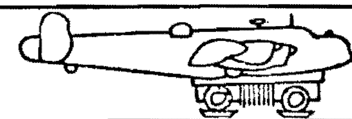
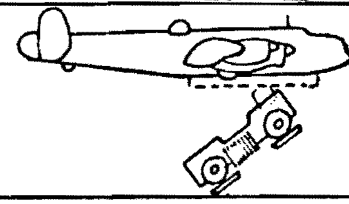
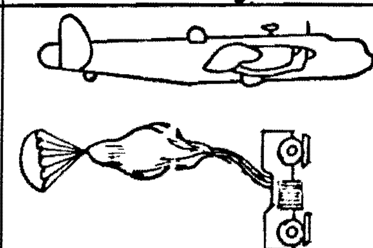
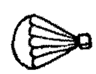
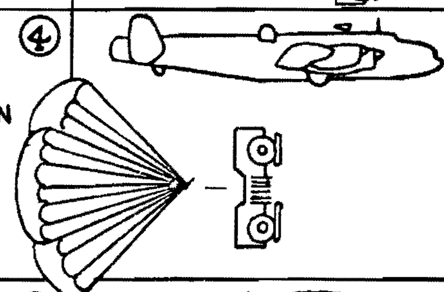
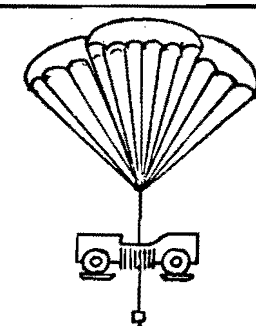
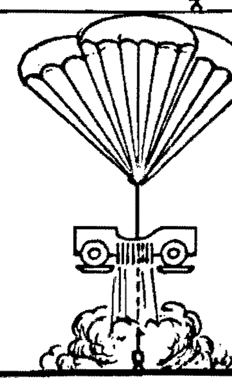
HALIFAX AIRCRAFT APPEARS, JEEP SLUNG FACING AFT IN FORWARD END BOMB CELL WITH DOORS OPEN. ①		2000 FEET
RELEASE, ENGINE END FALLS, REAR RETAINED BY AUXILIARY HOOKS UNTIL 2° TILT IS REACHED WHEN JEEP FALLS CLEAR — PARACHUTE PACK LIFTED OUT BY STATIC LINE WHEN ②		2000 FEET
③ PIN IS PULLED OUT RELEASING PILOT 'CHUTE WHICH DRAWS OUT MAIN CANOPIES FROM PACK.		2000 FEET
④ MAIN CANOPIES FULLY WITHDRAWN AND DEVELOPING, PILOT PARACHUTE FLOATS CLEAR WITH PACK. 		1800 FEET
⑤ CANOPIES FULLY DEVELOPED, JEEP STABILISED AND DESCENDING VERTICALLY AT 40 FEET PER SECOND. 10 SECONDS AFTER RELEASE, TIME DELAY OPERATES ALLOWING PLUMMET TO PAY OUT TO 15 FEET VERTICALLY BELOW JEEP. CIRCUIT NOW ARMED FOR FIRING ROCKETS.		1600 FEET
⑥ JEEP 15 FEET ABOVE GROUND, PLUMMET STRIKES GROUND AND INITIATES ROCKETS. JEEP THEN DECELERATES AND COMES TO REST AT GROUND LEVEL.		15 FEET

Figure 10 — Dropping a Jeep by Means of Parachutes and Rockets

scheme has since been discarded because of the very accurate location of the rockets required to keep from upsetting or tilting the jeep during the period of deceleration. The rockets now are mounted at the point where the three parachute canopies are joined together. The individual rockets are tilted slightly outward to direct their fire away from the load being carried.

This sytem would eliminate entirely the need for gliders, assault transports, or any other specialized types of aircraft for landing heavy equipment during the initial stages of an operation. The element of surprise would be maintained as the enemy would not know whether the bombers are on a bombing mission or on an airborne mission. However there appear to be several disadvantages. Some of these are: the design of the large parachutes which would be necessary for very heavy equipment; the complex nature of the packing and loading operation which would be necessary to insure that the system doesn't become fouled during deployment; the probability that items might not be spotted properly and might be scattered or dropped on top of each other; the inability to drop men with their equipment; and the necessity of diverting bombers to troop carrier operations when those bombers might be urgently needed to support the airborne operation.

In spite of the complexity and apparent unreliability of this system at the present time, it is felt that the British work should be closely watched and that development work should be undertaken in this country at such time as British progress warrants doing so.

RECONNAISSANCE AIRPLANE FOR AIRBORNE OPERATIONS

There appears to be a need for the development of a light observation-type airplane which can be carried or towed to the combat zone during an airborne operation. This airplane should be as simple as possible and capable of safe flight in the hands of untrained personnel after a brief period of ground instruction. It should be spin-proof and its ground worthiness should be such as to permit operations on rough or plowed ground and in reasonably high grass. It should be possible to take it into the combat zone by towing it as a glider or by carrying it with wings folded inside a cargo airplane or glider. If an airplane with folding wings is designed, the possibility of making it roadable at moderate speeds (with wings folded) should be considered.

The approximate performance characteristics of this aircraft should be as follows:

Maximum Speed	80 mph
Stalling Speed	30 mph
Take-off Run	200 ft
Landing Run	100 ft
Range	150 miles

This should be a single-seat airplane but provision should be made for carrying one passenger in an emergency. The performance characteristics quoted above are for operation with one passenger.

AIRCRAFT WITH JETTISONABLE CARGO COMPARTMENTS

This scheme involves the use of specially designed aircraft from which the cargo compartments can be jettisoned. The plane is flown in on a landing approach at as low a speed as possible. At a point just prior to touchdown the cargo compartment is released automatically less than a foot from the ground. The cargo compartment then becomes a separate vehicle running along the ground while the aircraft climbs away and returns to its base. The cargo compartment would be steerable by the operator and might well be a standard ground vehicle of the future. It would be equipped with special deceleration devices to shorten its ground run after release from the mother ship, following which it could go into action on the ground under its own power. There would be no obstruction of the landing zones as the cars could drive away immediately after landing; and no time would be lost unloading since the aircraft would be on its way back for another load immediately. The cargo compartment could be lightly armored, thus giving some protection to the airborne troops both in the air and on the ground. However, the ground vehicles might be easily damaged in drops on rough terrain and crosswind dropping might be extremely dangerous.

Even if the cargo compartments could not be successfully dropped "on the go" the basic idea still merits some attention. During the current war entire gliders have been equipped to perform certain utility services after landing in the combat zone. The CG-4A glider, for example, has been converted into a weather station, field kitchen, radio station, air traffic control tower, photo laboratory, radar station, repair and maintenance shop, and ice cream maker. The use of a glider in this manner involves tying up a whole aircraft, which is difficult to move, on the ground. Using a detachable cargo compartment for this purpose, these same services could be performed in a much more efficient manner while the flying part of the airplane would be available for further use.

GLIDER PICK-UP EQUIPMENT

Glider pick-up equipment has been developed during the war for retrieving gliders from small fields. This equipment involves the use of a cargo airplane equipped with a reel of cable attached to a special brake. The cargo airplane has a long pole which carries the end of the cable with a hook on it. By flying the airplane close to the ground, the cable is hooked on to the tow rope of the glider, the tow rope being held between two vertical poles about ten feet above the ground. The reel first releases cable at the speed of the towplane, but the brake is quickly and smoothly applied, arresting the reel and in this manner accelerating the glider to the speed of the towplane.

Although this equipment has been developed to a high state of reliability, it has had limited usefulness during the war. In actual combat operations, it is not considered tactically sound to permit cargo airplanes to fly over enemy territory solely on retrieving operations. More often cargo airplanes are used for air landing of additional supplies for the operation and they tow away one of the gliders on each trip. This method is much more economical of aircraft and gasoline, provided that a suitable airstrip is available for towing away the gliders. However, in training operations and in maneuvers the pick-up system is quite useful for retrieving gliders which have made forced or practice landings in very small fields.

It would appear wise to continue the development of pick-up equipment so that it is possible to retrieve the largest gliders procured. However, this development work should be terminated if it becomes apparent that gliders will be replaced by other types of aircraft in future airborne operations.

ROTARY-WING AIRCRAFT

Rotary-wing aircraft, when developed to a higher degree, potentially offer many advantages important in airborne operations. It is to the interest of the improved efficiency and versatility of future airborne armies to foster the development of rotary-wing aircraft and to direct a part of the development toward the needs of airborne armies. Present-day helicopters may appear to be unsuitable for airborne operations, but it must be remembered that rotary-wing aircraft are still in their infancy and still lack much development work before their performance, structural, and vibration problems are solved: it must also be remembered that they have never been designed for use in airborne operations.

Rotary-wing aircraft are the only aircraft capable of making the vertical landings so desirable in airborne operations, and they are the only aircraft which can operate practically independently of terrain. Where the landings of fixed-wing gliders are restricted or prohibited by lack of suitable terrain, a rotary-wing glider or a helicopter, capable of vertical landings, can be used. Where aerial supply and evacuation await the construction of airstrips for fixed-wing aircraft, helicopters can land and take off from unimproved terrain. Cargo carrying helicopters of from five to six tons gross weight are considered a possibility even with present-day limited knowledge.

Rotary-wing aircraft will always be low-speed and short-range vehicles. Some improvements are to be expected. The high speeds of less than 100 mph for helicopters may be boosted to between 150 to 200 mph, and their present ranges of a few hundred miles increased slightly. Even greater increase in high speed and range may be obtained by departing somewhat from the basic helicopter configuration and developing the gyrodyne and the cyclogyro. Still, the high speed and range performance of rotary-wing aircraft will never be equal to that of a fixed-wing aircraft; therefore, their employment must be reserved for those missions on which a fixed-wing aircraft cannot be used, where the vertical landing and take-off abilities of rotary-wing aircraft are a necessity, and the low-speed and short-range characteristics are acceptable.

More efficient designs of rotary-wing aircraft incorporating jet propulsion, boundary-layer control, and other improvements, as well as the possible introduction of the cyclogyro and gyrodyne with superior performance, as successors to the helicopter, are discussed in "The Airplane: Problems and Prospects", an AAF Scientific Advisory Group report.

PARACHUTES

Much work remains to be done on the development of parachutes which are more suitable for the use of paratroopers. The problems of stability (elimination of ossillations) and reduction of opening-loads are particularly important. The ribbon-type parachute was developed by the Germans in an effort to solve these two problems; however, for paratrooper use, this parachute has the disadvantages of a long opening time and a high rate of descent.

Work is now being done in this country on the elimination of oscillations by gradually increasing the porosity of the parachute fabric from the vent (top) to the bottom part or skirt. A progressively coarser weave of fabric is used to increase the porosity. The project shows promise of perfecting a non-oscillating parachute, with normal rate of descent, which will still open rapidly (two seconds) for jumps from very low altitudes.

When jumps are being made from higher altitudes, say 1500 ft or more, it is possible to reduce opening loads by delaying the full opening of the parachute. One project under way involves the use of a reefing line around the skirt of the parachute. By connecting the reefing line to a timing device, it will be possible to make the parachute open gradually in steps (1/4, 1/2, 3/4, and then full) and to delay the full opening time from one to six seconds. The desired delay time can be selected and preset. The timing mechanism can be connected to a barometric opening device to insure opening of the parachute for jumps from high altitudes.

Research also should be continued on the development of suitable, lighter fabrics for parachutes and on quick-release harnesses so that the paratrooper can get rid of his parachute quickly without removing any of his combat equipment.

COORDINATION OF AIRCRAFT CARRYING CAPACITIES WITH EQUIPMENT TO BE CARRIED

FROM THE EARLY STAGES OF THE WAR TO THE PRESENT

During the early stages of the war, transport aircraft procured were commercial off-the-shelf articles, hastily and only partially adapted for the unique requirements of airborne operations. Wider doors were provided, stronger floors installed, and other minor alterations were made; but such aircraft as the C-47, C-46, and C-54 had been initially designed for commercial operations and they were not changed basically by these minor modifications. Airborne warfare was new, and shortages of aircraft, materials, and equipment for fighting conventional warfare were so critical that little could be spared for the new.

The development of troop gliders was started before the war, but the existing conception of their use at that time was merely as personnel carriers. Late in 1941, redesign of the CG-4A (then XCG-4) glider to carry the 1/4-T jeep and the 75-mm Pack Howitzer was started. This project was based on the personal observations of an Air Technical Service Command (then Materiel Division) officer who had been in England and had seen the British plans for the "Hamilcar," a light-tank-carrying glider. The Jeep and 75-mm Howitzer were chosen because they were the largest items which could be made to fit in the CG-4A without necessitating complete redesign of the glider.

As the war progressed and it became possible to initiate designs of new aircraft for airborne operations, liaison was established on airborne matters between the Air

Forces and the Ground Forces. It was decided that both the C-82 airplane and CG-10A glider would be designed, so as to be capable of carrying the 155-mm Howitzer. However, by the time the prototype aircraft were completed, the 155-mm Howitzer had been equipped with larger tires to facilitate operation in sandy terrain. While the small-tired 155-mm Howitzer can be carried in both the C-82 and the CG-10A, the large-tired gun is a few inches too wide for the C-82.

In August 1944 a joint AAF and AGF conference was held to determine the military characteristics to be incorporated into the design of future cargo-type aircraft to make possible the air landing of standard components of the Army in large-scale airborne operations. At this meeting, the following list of heavy battle equipment was submitted as being considered essential by the Army Ground Forces in airborne operations involving a division and a corps:

DIVISION EQUIPMENT

Type of Equipment	*Weight (lb)*	*Height (in.)*	*Width (in.)*	*Length (in.)*
10-T Wrecker M-1	38,330	122	108	348
13-T Wrecker M-5	28,300	104	100	191
Bulldozer with Blade	22,400	106	156	188
4-T Wrecker M-1	21,700	118	101	292
Compressor, Air, Truck Mounting	21,164	89	101	262
Compressor, Air, Truck Mounting	14,300	93	90	254
155-mm Howitzer	11,966	71	98	318

CORPS ARTILLERY AND ARMOR

Type of Equipment	*Weight (lb)*	*Height (in.)*	*Width (in.)*	*Length (in.)*
Wagon Transport M-3 (In 4 component loads)	91,400	(Total weight, including items listed below).		
240-mm Howitzer	32,000	—	336	—
Carriage Wagon M-2	—	84	111	—
Carriage M-1	39,425	—	—	—
Medium Tank-T26E1 (Experimental)	85,700	110	137	324
Medium Tank-M4A4	79,900	112	103	339
Tractor (Heavy) M-6 (Crane is not essential & is not included in figures)	75,000	103	120	258
Medium Tank-M4A3	69,600	112	103	233
Medium Tank-M4	67,300	116	103	232
155-mm Gun M-1	39,900	103	99	411
Light Tank M-24	38,000	100	112	216
Light Tank M-5A1	34,073	91	89	171
8-in. Howitzer (could replace 155-mm Gun)	31,799	100	99	402
Tractor	31,800	99	97	203

Inspection of this equipment list reveals a sharp break in weight from the heaviest corps artillery peice, the 155-mm Gun M-1, weighing 39,900 lb, to the lightest medium tank,the M-4, weighing 67,300 lb. It was therefore agreed that two types of aircraft should be developed: (1) a heavy cargo carrier with maximum payload of 40,000 lb; and (2) a special cargo aircraft capable of transporting service type medium tanks. Accordingly, development of these two types has been initiated. However, there has been no control established to insure that the dimensional characteristics of the equipment listed will not change so that the equipment will still fit into the aircraft when the latter become available for service use several years from now.

At this same meeting, a payload of 10,500 lb was established as the top limit on all future glider development. There was a subsequent request from Army Ground Forces for the development of two future transport aircraft: one capable of transporting a piece of equipment 20 T in weight and 3500 cu ft in displacement; and another capable of transporting a piece of equipment 45 T in weight and 4500 cu ft in displacement. It was stated that the development of gliders must be comparable to the development of aircraft. With regard to the aircraft with a 45 T capacity, the Preliminary Board Study of the AGF Postwar Equipment Review Board (circulated in May, 1945) recommended the development of transport aircraft capable of transporting equipment weighing up to 50 T and displacing 5000 cu ft.

In April 1945, a conference was held to determine the characteristics of future glider designs. At this time, it was decided that development of two gliders having the following characteristics would meet Army Ground Forces requirements:

Glider	*Useful Load (lb)*	*Displacement (cu ft)*	*Cargo Compartment Characteristics*		
			Length (in.)	*Width (in.)*	*Height (in.)*
1	8,000	1,200	288	92	78
2	16,000	1,985	360	112	85

The dimensional data for these gliders were based on a preliminary study of possible loads which would have to be carried during the initial phases of an airborne operation. It was stated that flying Glider No. 1 only partially loaded would be preferable to the development of an additional smaller glider for the assault phase of an operation. The 16,000 lb useful load of Glider No. 2 exceeds the previously set limit of 10,500 lb (August, 1944 conference). This second conference was held under the auspices of the Air Technical Service Command, and the military characteristics of the proposed gliders have not yet been fully processed through the Air Staff. The cargo compartment dimensions of Glider No. 2 have been recently changed to 420 x 104 x 95 in., (2400 cu ft), on request from the Army Ground Forces. The Equipment Review Board report, referred to previously, recommends the development of the following gliders: an assault glider capable of transporting a piece of equipment weighing 4 T and displacing 1000 cu ft; and a cargo glider capable of transporting a piece of equipment weighing 10 T and displacing 3000 cu ft.

Thus, as the development of an increasing number of aircraft specifically for airborne operations has been initiated, there has been an increasing amount of liaison work between Air Forces and Ground Forces on the important question of ground equipment to be carried by future aircraft. However, the brief summary of events given above shows the need for two things: (1) some method of limiting the dimensional and weight characteristics of items of ground equipment after the development of aircraft to carry those items has been initiated; (2) a more comprehensive approach to the problem of determining cargo compartment dimensions and weight capacities of future cargo aircraft.

PROMULGATION OF THE POLICY OF "AIR TRANSPORTABILITY"

The close and active contact between air and ground on airborne matters is based on the firm thesis that the potentialities of airborne operations are unlimited if the possibilities are successfully exploited in the future design of both aircraft and equipment, and that the capability of deploying ground force units by air will revolutionize military strategy and tactics.

In carrying out their share of the job, the Army Air Forces have accepted the following statement as a goal for troop-carrier aviation: "To posses the ability to transport by air into a zone of combat any combat or essential service unit of a standard division, corps, or army." To achieve this objective, appropriate AAF agencies have been directed to continue exhaustive research in the development of larger and more efficient transport aircraft. In addition to this, the Air Forces have sponsored the introduction of the policy of "Air Transportability."

The following tentative draft of this new policy has been informally approved and is being proposed by WDGS, G-4, to the three major commands (AAF, AGF, and ASF) for formal approval: "In preparing statements of military characteristics it shall be stated in such characteristics that the item of equipment in question shall be capable of being transported by air, either as a whole or in a disassembled condition' if such a requirement will not materially impair the primary purpose of the item of equipment. Weight and dimensional limitations governing the application of this policy shall be supplied by the Commanding General, AAF, and will be based upon a thorough consideration of then-existing and projected transport type aircraft. Such aircraft limitations and changes thereto shall be supplied to all technical committees and shall be carefully employed by such committees to determine insertion or elimination of the statement regarding air transportability of any item of equipment in the military characteristics therefor. It is the intent of this policy that all possible items of equipment shall be transportable by air."

This policy, when formally approved, will be made a part of those War Department regulations which deal with the formulation and adoption of military characteristics for any new equipment introduced into the Army.

PROGRAM FOR THE FUTURE

The pattern for the future has been laid. There must be no mistakes about the ultimate aim, no half-measures in the drive to achieve it. The army which can travel by air will win the next war. We must plan now to do the work which will eventually permit the entire United States Army to deploy by air and to operate by air. This means carrying all of the Army's equipment by air in the simplest, most efficient manner possible. Individual aircraft must be small enough to suit tactical requirements. But each aircraft must be used efficiently, so that the smallest possible total number of aircraft and as few different types as possible are required. The following are the requirements for achieving this objective:

1. *An Overall Study of the Problem.*

As more time becomes available for future planning, an overall, combined Air Forces-Ground Forces study of the problem of transporting armies by air should be made. The general objective of this study should be "the determination of the optimum sizes of future cargo aircraft so that the United States Army can be moved by air for the required distances in the most efficient manner possible, with full regard for tactical requirements."

The progressive steps which would be taken in making such an overall study are visualized as follows:

a. Data would be collected on the weight and dimensional characteristics of all items which go to make up the Army. Artillery, armor, trucks and trailers, engineer equipment, and other miscellaneous items should be covered. (Most of this data already exists but is scattered throughout various publications in incomplete form and needs to be brought together and completed.) Particular emphasis should be laid on the inclusion of the best data available on research items and items undergoing modification or further development. These data will then give an indication as to the trends in weight and size of the various items of equipment under the general categories mentioned.

b. These data on weights and dimensional characteristics would be studied by properly qualified tactical personnel to determine answers to such questions as:

(1) Number of personnel to be carried into combat in the same aircraft with a particular gun or truck;

(2) Gross weights of trucks and trailers going into combat, including crew, fuel, and cargo;

(3) Number of rounds of ammunition to accompany guns into combat in the aircraft in which the gun is carried. The object of this part of the work would be to insure that an optimum balance is made between the need for landing men and equipment which are going to be used together in the same aircraft, and the practical and tactical requirements that the sizes of the aircraft needed not be permitted to get too large.

c. The various loads and items would all be classified according to the phase of an airborne operation in which they would be required. All lifts needed for the initial or assault phase of an operation would have to be carried in a ready-to-fight condition, but these loads would have to be adjusted in weight and size, so as to be capable of being carried in the comparatively small gliders and assault transports which would be used in this phase of an operation. Large and bulky items of maintenance equipment, which might not be needed until a few days after an operation had been started, would be marked for special study as to the feasibility of disassembly, if they could not be carried in the larger transports which would be used in the final phases of an airborne operation (after landing strips had become available in the combat zone). In all such cases, however, delivery in a disassembled condition would be planned only when considered practicable and acceptable to the Ground Forces. (This work has all been done for the Airborne Division in that individual loads were picked to utilize the capacities of aircraft and gliders made available. For the standard division, corps, and army, with time available to plan, we should consider tactical requirements first, and then adjust future aircraft capacities to suit those requirements.)

d. The various loads would then be laid out to scale to determine space requirements, weight distribution, and methods of loading in aircraft, so that loads arrive in combat ready to unload and go into action in minimum time. The space requirements should be practical, and should allow for proper clearances to insure ease of loading and hasty unloading without damage to the aircraft.

e. The weight and dimensional data on the various loads would then be used by the Air Forces to determine what cargo-compartment dimensions and weight-carrying capacities will permit the lifting of various ground units by the smallest practical number of different types, consistent with tactical requirements, and by the smallest total number of aircraft.

Figures 11A, 11B, 11C, and 11D (followed by a key listing the equipment shown) give an idea as to the possible appearance and usefulness of this study. The numerical data for these figures were taken from various field manuals and supply bulletins; although they are most probably accurate, they should not be considered so, and are used here for illustrative purposes only. (Net weights were used for the various items except when they were not available, in which case gross weights are shown.) Sketched on these figures are the dimensional and weight characteristics of the following three airplanes:

No. 1 carries 6 T in a displacement of about 2430 cu ft;

No. 2 carries 20 T in a displacement of 3650 cu ft; and

No. 3 carries 50 T in a displacement of about 3200 cu ft (appears in Fig. 11D only).

AIRPLANE NO. 1. One preliminary study showed that in order to move a Standard Infantry Division, about 1030 airplanes of this type would be needed on a weight basis, whereas about 1350 would be needed on a volume basis. Thus, the cargo space of 1350 airplanes would be occupied and yet, on the average, the airplanes would be carrying only approximately 76% of their load capacity; this means a payload of about 9200 lb per airplane. The cargo compartment dimensions of this airplane are very similar to those of the C-82. The C-82 can be flown over a radius of about 1050 miles, when fully loaded, if the payload is about 9200 lb. If we use the C-82 to carry the standard infantry division over a raduis of, say, 500 miles, then each airplane will only be about 62% loaded. The question is: Will this airplane be used most frequently for moving standard infantry divisions over a radius of 1050 miles, or will the radius be nearer 500 miles? If it is the latter, should the size of the cargo compartment be increased to permit loading the airplane fully for the shorter flights? These figures are approximate and must not be assumed to be directly applicable to the C-82. However, they do indicate how advantageous it would be to have complete data available when new airplanes are still on the drafting board. Going further, the charts show that a total of about 14 times (marked by arrows) which could be carried in this airplane on a weight basis, cannot be carried because they will not fit into the cargo compartment. Special studies should be made of these items to deter-

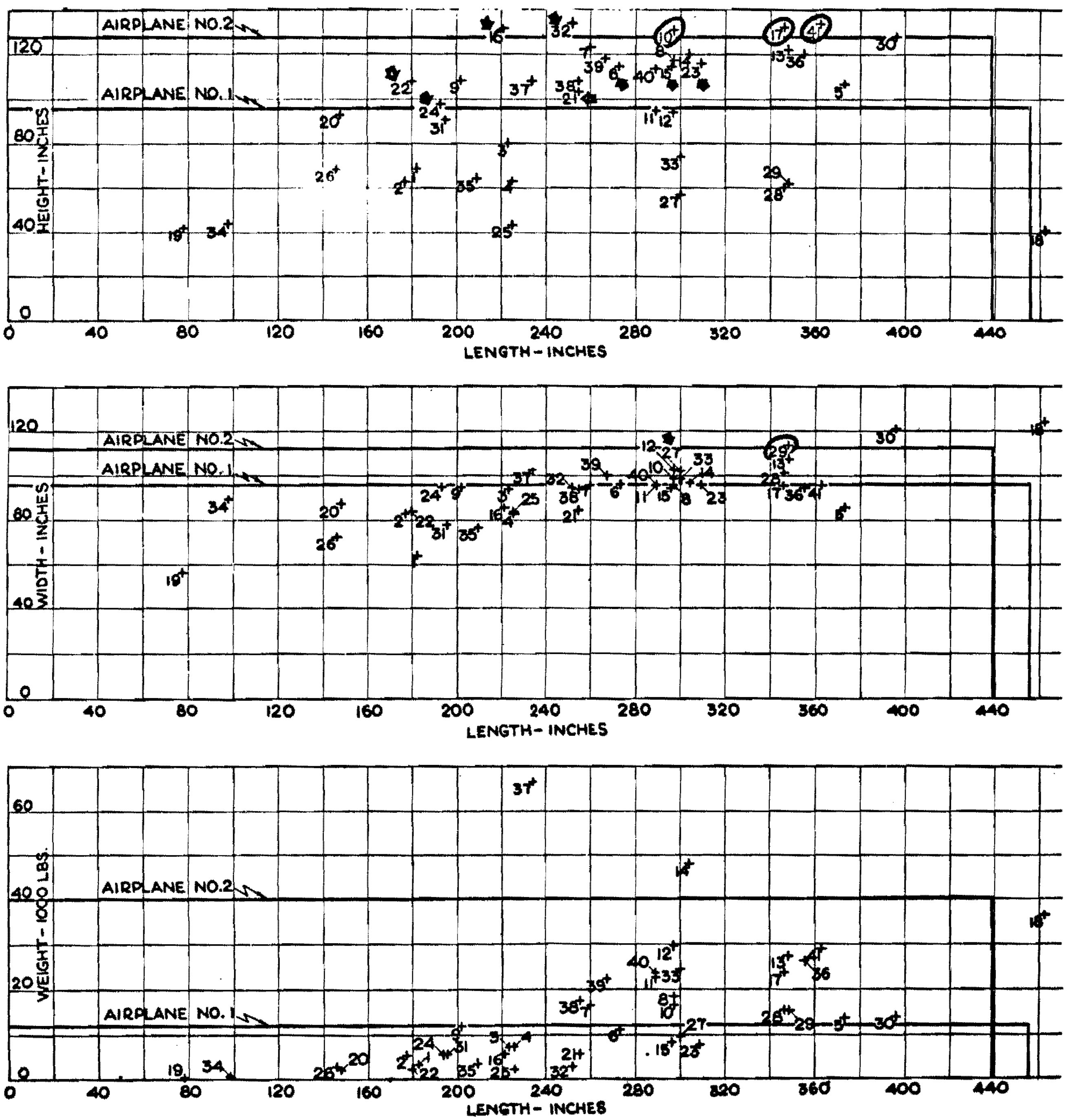


Figure 11-A — Weights and Dimensions of Army Equipment (Trucks, Trailers and Miscellaneous)

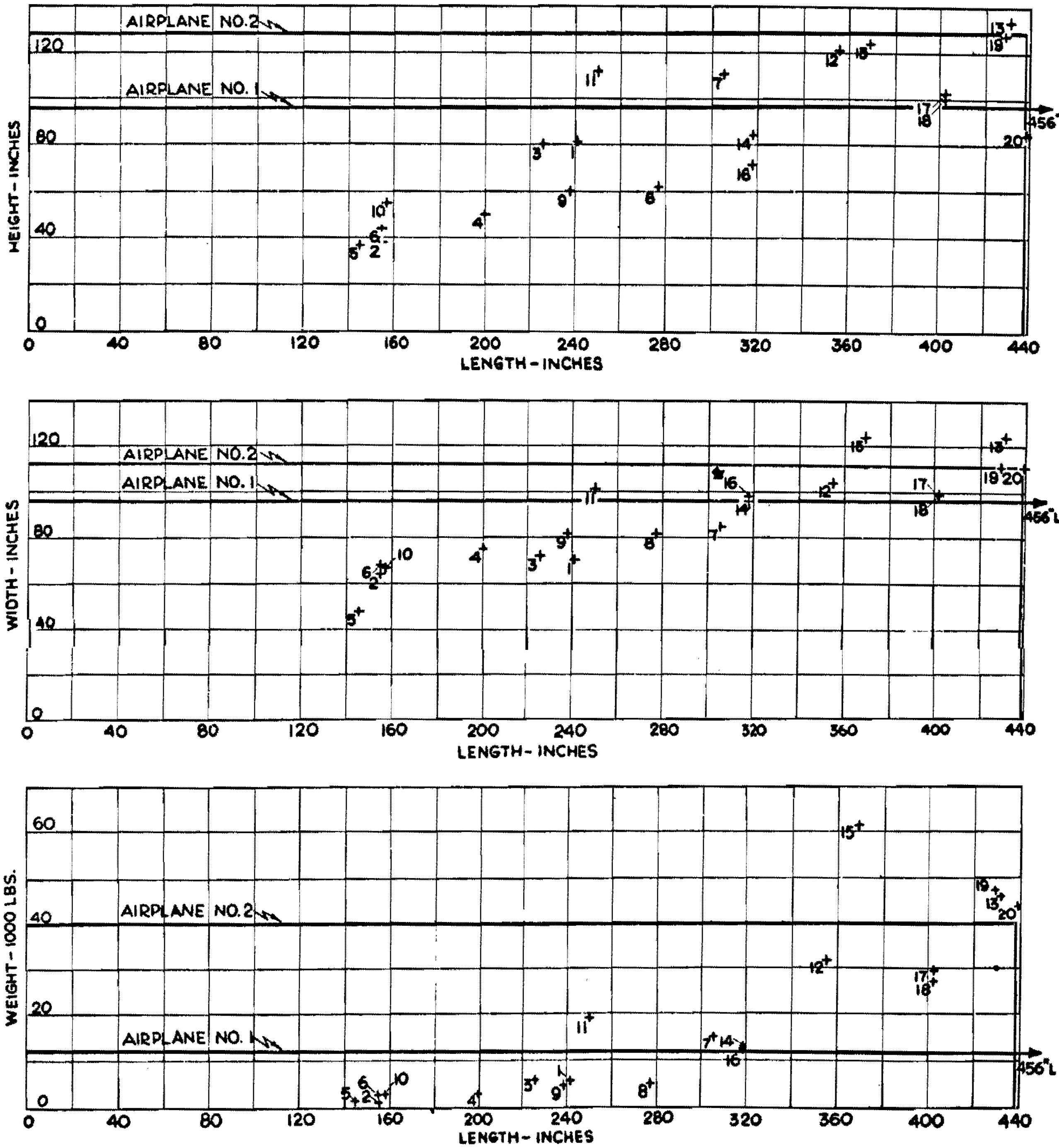


Figure 11-8 — Weights and Dimensions of Army Equipment (Towed Weapons)

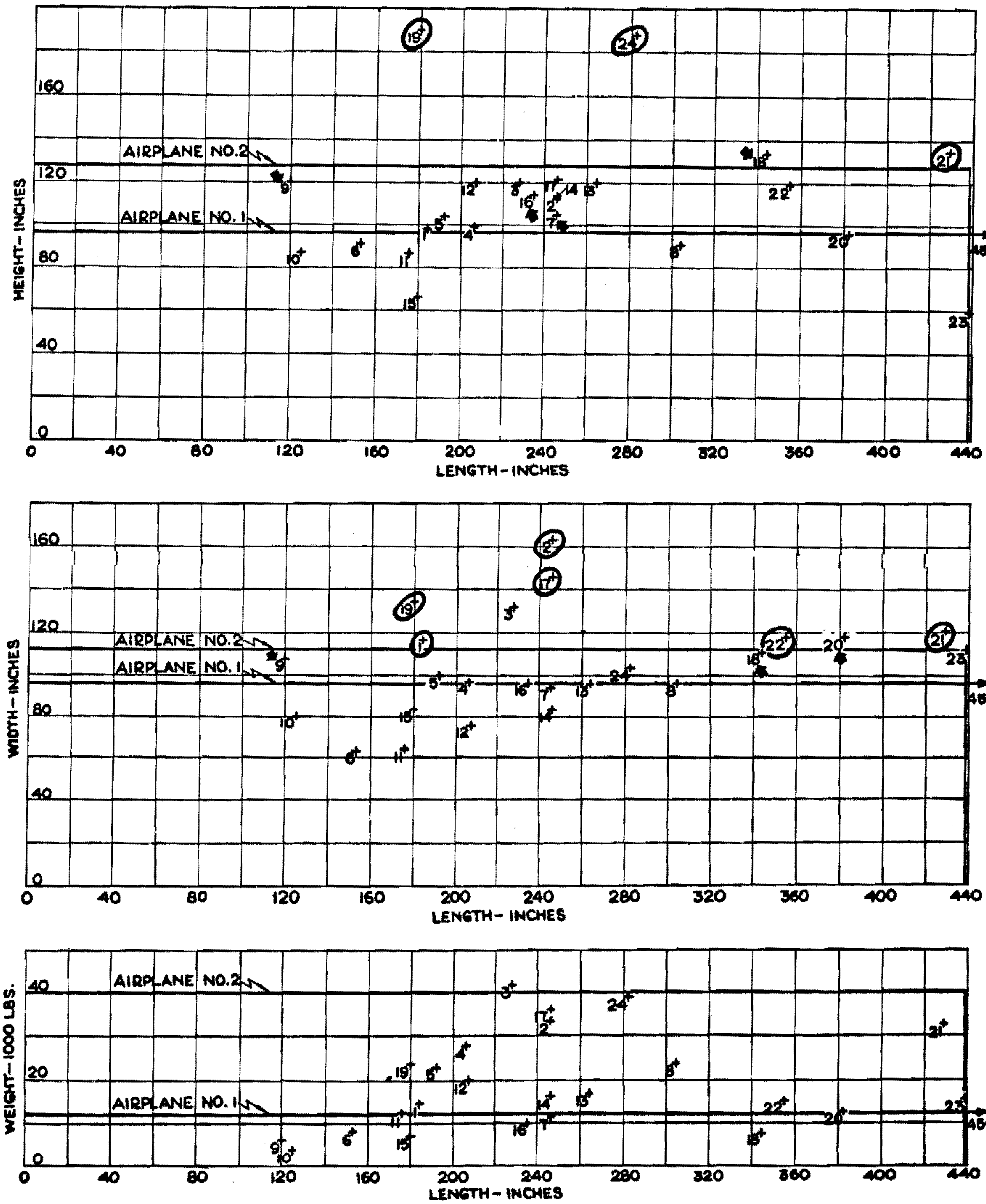
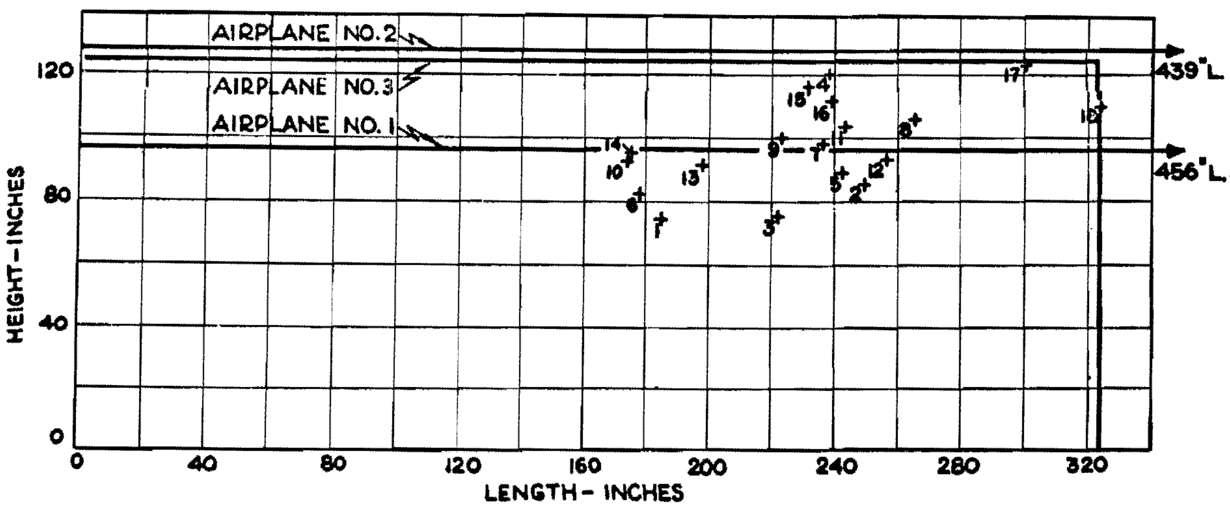
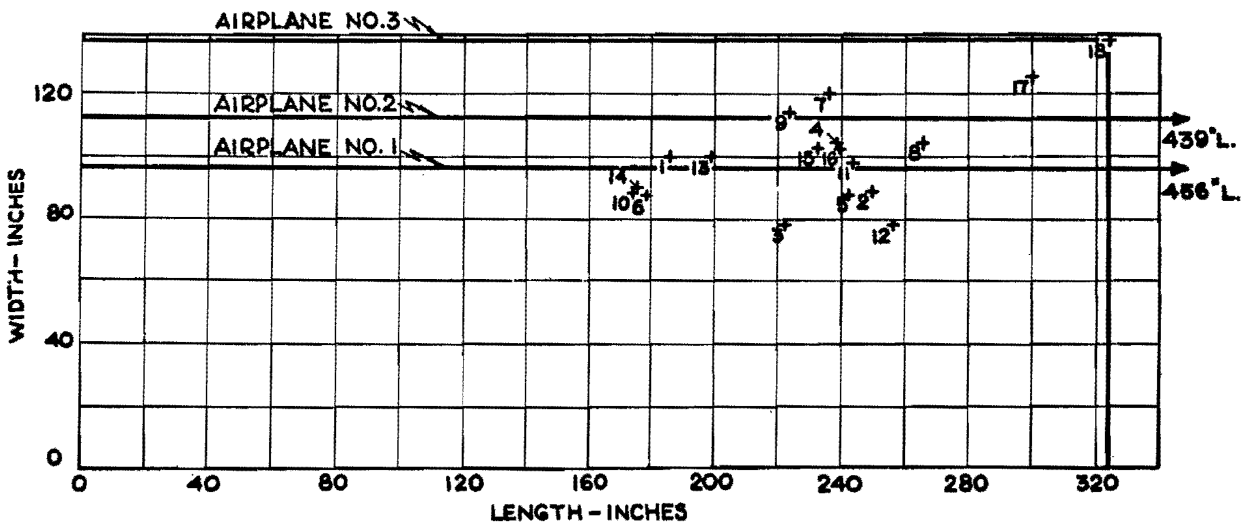


Figure 11-C — Weights and Dimensions of Army Equipment (Aviation Engineer Equipment)





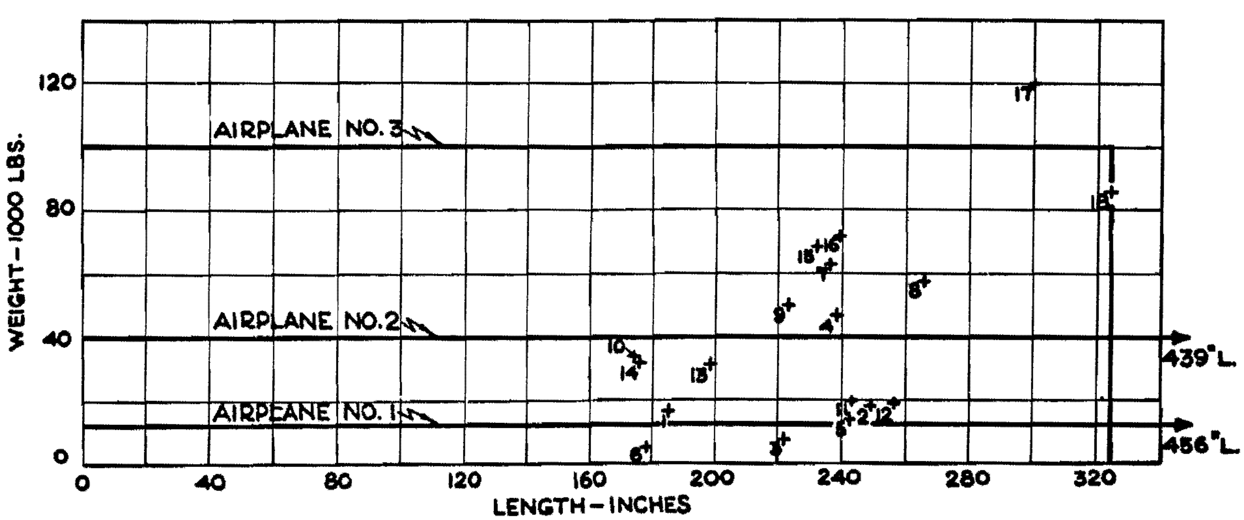


Figure 11-D — Weights and Dimensions of Army Equipment (Combat Vehicles and Tanks)

11A

TRUCKS, TRAILERS, & MISCELLANEOUS

TRUCKS

1 - 1/4-TON, AMPHIBIAN
2 - 3/4-TON, WEAPONS CARRIER, 4X4
3 - 1-1/2-TON, 4X4, AUGER, EARTH, MTRZD, M2
4 - 1-1/2-TON, 6X6, CARGO, W/W
5 - 2-1/2-TON, AMPHIBIAN
6 - 2-1/2-TON, SHOP, MTRZD
7 - 2-1/2-TON, WATER PURIFICATION, 6X6
8 - 4-TON, 6X6, CARGO, LWB, W/W
9 - 4-5-TON, 4X4, TRACTOR, W/W
10 - 5-6-TON, 4X4, TRACTOR, PONTON, C.O.E., W/W
11 - 6-TON, 6X6, PRIME MOVER, W/W
12 - 7-1/2-TON, 6X6, PRIME MOVER, W/W
13 - 10-TON, 6X6, HEAVY WRECKER, M1
14 - 40-TON, 6X6, TANK RECOVERY VEHICLE, M25 (TRUCK-TRACTOR M26, ONLY)

SEMI-TRAILERS

15 - 1-1/2-TON, VAN, K-55 (SIG)
16 - 6-TON, GROSS, VAN
17 - 10-TON, GROSS, MAP REPROD. EQUIP.
18 - 40-TON, GROSS, TANK RECOVERY VEHICLE, M25 (SEMI-TRAILER, M15 ONLY)

TRAILERS

19 - 1/4-TON, TELEPHONE CABLE SPLICER, K38 (SIG)
20 - 1/2-TON, VAN, PUBLIC ADDRESS
21 - 1-TON, COMMUNICATIONS
22 - 1-TON, VAN, 2-HORSE
23 - 1-1/2-TON, COMMUNICATIONS VAN, K-35 (SIG)
24 - 2-TON, SMOKE GENERATOR, M7
25 - 2-1/2-TON, UTILITY, POLE TYPE (TYPE I)
26 - 5-TON, TELEPHONE CONSTRUCTION, K-37 (SIG)
27 - 8-TON, FULL, LOW BED
28 - 16-TON, FULL, LOW BED
29 - 20-TON, FULL, LOW BED
30 - SCRAPER, ROAD, TOWED, 8-CU. YD.

MISCELLANEOUS MOTOR VEHICLES

31 - AMBULANCE, 3/4-TON, 4X4
32 - CRANE, TRUCK MNTD, 3/8-CU. YD.
33 - GRADER, ROAD, DIESEL ENGINE, 12-FT. MOLDBOARD
34 - MOTORCYCLE, W/SIDE CAR
35 - SEDAN, 5-PASSENGER, MEDIUM
36 - SHOVEL, CRAWLER MNTD, 1/2-CU. YD.
37 - VEHICLE, TANK RECOVERY, M32
38 - TRUCK, 4-TON, 6X6, DUMP
39 - TRUCK, 4-TON, 6X6, WRECKER COMPLETE W/EQUIPMENT
40 - TRUCK, 6-TON, 6X6, PRIME MOVER W/WINCH
41 - SEMI-TRAILER, TECHNICAL SUPPLY, 10-TON GROSS

11B

TOWED WEAPONS

1 - 37-MM GUN, AA, M3A1
2 - 37-MM GUN, AT, M4A1
3 - 40-MM GUN, AA, M2
4 - 57-MM GUN, AT, M1A2
5 - 75-MM PACK HOWITZER, M1
6 - 75-MM PACK HOWITZER, M3A3
7 - 3-INCH GUN, AA, M2A2
8 - 3-INCH GUN, AT, M1
9 - 105-MM HOWITZER, M2
10 - 105-MM HOWITZER, M3A1
11 - 90-MM GUN, AA, M1A1
12 - 90-MM GUN, AA, M2
13 - 105-MM GUN, AA, T4
14 - 4.5-INCH GUN, M1
15 - 4.7-INCH GUN, AA, T2
16 - 155-MM HOWITZER, M1
17 - 155-MM GUN, M1
18 - 8-INCH HOWITZER, M1
19 - 240-MM HOWITZER, M1 - CARRIAGE VEHICLE
20 - 240-MM HOWITZER, M1 - CANNON VEHICLE

KEY

11C

AVIATION ENGINEER EQUIPMENT

TRACTORS

1 - CRAWLER-TYPE, 35 DBHP, W/ BULLDOZER
2 - 80-HP, D-7
3 - 115-HP, D-8
4 - MEDIUM, HIGH SPEED, 18-TON, M4
5 - MEDIUM, HIGH SPEED, 13-TON, M5

MISCELLANEOUS

6 - COMPRESSOR, AIR, TRLR-MNTD, 315 CFM
7 - DISTRIBUTOR, BITUMINOUS, TRLR-MNTD, 1,250-GAL.
8 - GRADER, ROAD, MTRZD, 12-FT. MOLDBOARD
9 - MIXER, CONCRETE 14-CU. FT., TRLR-MNTD
10 - PUMP, ASPHALT, TRLR-MNTD
11 - ROLLER, ROAD, TANDEM 2-AXLE, 5 TO 8 TON
12 - ROLLER, ROAD, 3-WHEEL, 10-TON
13 - SHOP EQUIPMENT, MTRZD, GENERAL PURPOSE REPAIR
14 - SHOP EQUIPMENT, MTRZD, MACHINE SHOP HEAVY
15 - SWEEPER, ROTARY, ONE-WAY SWEEPING
16 - TANK, ASPHALT, TRLR MNTD, W/STEAM COILS, 1,500-GAL.
17 - TRACTOR, CRAWLER TYPE, 70-90 DBHP, W/BULLDOZER, TILTING OR COMPLETE W/ANGLEDOZER
18 - CRANE, TRACTOR OPERATED, NON-REVOLVING, 20-TON, 20-FT. BOOM
19 - DITCHING MACHINE, LADDER TYPE, 8-FT. DEPTH, 18-24 INCHES WIDE
20 - GRADER, ROAD, TOWED, LEANING WHEEL, HAND CONTROLLED, 12-FT. MOLDBOARD
21 - SCRAPER, ROAD, MTRZD, 12 CU YD.
22 - SCRAPER, ROAD, TOWED, 8 CU. YD.
23 - SEMITRAILER, LOW BED, 20-TON, W/DOLLY
24 - SHOVEL, CRAWLER-MNTD, 3/4 CU. YD.

11D

COMBAT VEHICLES & TANKS

CARS

1 - ARMORED, L, M8, 6X6
2 - HALF-TRACK, M3A2
3 - SCOUT, 4X4 M3A1

CARRIERS

4 - CARGO, M30(T14)
5 - MORTAR, M4

CARRIAGES, MOTOR

6 - GUN, 75-MM HOWITZER, M8
7 - GUN, 3-INCH, M10A1
8 - GUN, 155-MM, M12
9 - HOWITZER, 105-MM, M7
10 - HOWITZER, 75-MM, M8
11 - MULTIPLE GUN, M15A1, (AA)
12 - MULTIPLE GUN, M16, (AA)

TANKS

13 - LIGHT, M3A3
14 - LIGHT, M5A1
15 - MEDIUM, M4 (105-MM HOWITZER)
16 - MEDIUM, M4A4
17 - HEAVY, M6
18 - MEDIUM, - T26E1 (EXPERIMENTAL)

mine whether or not they could be modified to fit in this airplane, or new items (which do the same job but fit in the airplane) developed to take their place; or, consideration should be given to the advisability of developing another airplane in this weight-carrying class with larger cargo compartment dimensions.

AIRPLANE No. 2. This is the airplane with a 20 T carrying capacity. If this airplane should be built to carry the items which wiegh 20 T or less listed in the narrative of the combined AAF"AGF conference given before (blade of bulldozer removed since it is 44 in. wider than any of the other items), the volumetric capacity of its cargo compartment would be about 3650 cu ft. (Note: The dimensions given at the conference for the 240-mm Howtizer appear to have been incomplete. Those assumed here are for the 240-mm Howitzer, M1, carriage vehicle and cannon vehicle, given in FM 101-10.) There are about eleven other items, encircled on the figures, in the Army which fall within the 20 T weight limitation, but which would not fit in this cargo compartment. Six of these could be accommodated if the cargo compartment were made six inches wider and six inches higher. This can probably be done since, as a troop carrier, the airplane will have to have a total cargo compartment volume of about 4000 cu ft, (25 cu ft per man, each man weighs 250 lb). Certainly the need either for increasing the size of the cargo compartment or for redesigning the items which will not fit should be considered now, when the airplane is just in the preliminary design stage.

AIRPLANE No. 3. This is the one which is capable of carrying 50 T. This aircraft could easily carry the largest medium tank, the T26E1 (experimental), with a 15,000-lb margin. It could carry this tank and all others which fall within its weight limitation with a cargo compartment displacing only about 3200 cu ft. If a troopcarrier airplane with this useful load were to be developed, the possibility of carrying the heavy tank, M6, under overloaded conditions would certainly be considered. The only troop carrier airplane being considered for development which will be anywhere near this size will have a payload of 70,000 lb, and will be capable of carrying the M4A3 tank. (The M4A3 is 3500 lb lighter and 6 in. shorter than the M4A4 which appears in Fig. 11D. FM 101-10 shows M4A4 tank weighing 71,900 lb.) Some consideration should be given to the possibility of carrying the T26E1 experimental medium tank in this airplane since, presumably, it is being developed for use along with or perhaps to replace other medium tanks.

Again, these examples are only approximate; they do not take into consideration the questions of combat loads and proper clearances between aircraft and load; they are not complete or conclusive, but are given for illustrative purposes only. Clearly, however, there is indicated the need for an overall consideration of the problem in order to insure proper direction of the cargo airplane development program and to insure that future aircraft will operate with maximum efficiency on those missions for which they will be most frequently used.

These examples also help to illustrate some of the following advantages which might come from this type of an overall study:

a. It will insure the coordination of cargo compartment dimensions and weight capacities of future aircraft with ground equipment to be carried and thus give maximum utility and efficiency.

b. It will show the trends in weight and sizes of various major classifications of ground equipment such as artillery, armor, transport vehicles, and engineer equipment. (Artillery and transport vehicles will probably decrease somewhat in size and weight, whereas, armor and engineer equipment may increase. Our study will show these trends exactly and provide data to guide designers of future cargo aircraft.)

c. It will indicate the necessity and/or advisability of developing special aircraft or special means of carrying by air the few unusually heavy or bulky items of equipment in the Army.

d. A means of control could be established to insure that aircraft or other means developed for the assault phase of an airborne operation are small enough so that initial landings do not become too much of a tactical problem and do not require excessively large or improved drop zones and landing zones.

e. It will tell us at all times just how much of the Army can be moved by air and what progress is being made in the quest for a completely air-transportable Army.

f. Items which are to be carried disassembled will be singled out for special attention as to ease of assembly and provision of means for tying down individually the various component parts of each item. Consideration would be given to the need for providing disassembly points on certain items of equipment, so that they can be carried in pieces in one or more smaller airplanes, even though they can be carried intact in a larger airplane.

g. When technical performance data on aircraft is combined with tables of organization and equipment for various ground units, this study will provide all of the data needed for compiling an additional section to the Staff Officer's Field Manual. This new section will show exactly what types of aircraft and how many aircraft of each type will be needed for various airborne operations.

It would probably take a qualified board of officers several months to carry out such a comprehensive study. They would also have to set up a system or process by which all new information and changes would be collected, and the study continually revised and brought up to date, perhaps on a semiannual basis. This time and effort would be well worth while as the project is a "must" for the future.

2. *Positive Coordination in Addition to Technical Liaison.*

During several conferences which were held in connection with the promulgation of the policy of air-transportability, there were discussed ways and means of implementing the policy and monitoring adherence to it. It was generally agreed that existing lines of technical liaison would do the job, provided that the representation of agencies not primarily concerned, was strengthened on the various technical committees.

It is felt that the work of the various technical committees and liaison officers should be supplemented by an annual review of the overall study outlined above. This review should be conducted on a fairly high staff level, and all available data on ground equipment and aircraft development should be up to date at the time the review is made. The liaison officers will know of all cases of incompatibility between aircraft cargo capacities and weights and sizes of ground equipment. The coordinating agency conducting this annual review should be charged with the responsibility of making the Army air-transportable; it should have the authority to direct the development of new aircraft with new capacities if necessary; it should also have the power to set limits on the reducible overall dimensions and weights of various categories and items of ground equipment, and to require the development of new items of ground equipment to replace items which cannot be carried by air. As long as the development of aircraft remains the responsibility of the Air Forces and the development of ground equipment remains the responsibility of the Ground Forces, the program of making the Army air-transportable will suffer, unless a coordinating agency is constituted with authority to direct research programs in such a manner that we end up with an army whose fighting power on the ground is not hindered or limited in any way, but which is capable of movement and deployment by air.

3. *The Design of Standard Ground Equipment Specifically for Air Movement.*

We have thus far, with very few exceptions, attacked the problem of stronger airborne operations from one side only. The approach has been to increase the capacity, performance, and utility of our aircraft. Very little work has been done on the design of equipment for air movement, compared to the great amount of work which has been done to increase the efficiency of our aircraft.

It is not the intention or the purpose of this section to advocate the development of special equipment for airborne operations. Future airborne units should be capable of the same sustained action as future ground units, and should be organized and equipped in accordance with this concept. Nor is it the purpose of this section to add credence to misdirected statements about great reductions in size and weight which should have been made by using light metal alloys, without noting that light alloys have not been available for general use during the war. The problem has to be considered separately for each different category of equipment.

American engineer equipment is the best of its kind. Reducing the weight of a tractor does not make sense, because it reduces the working capacity of the vehicle. Special-purpose vehicles, tailored to fit certain aircraft, can be and have been developed, notably the Clark Crawler and the Case Airborne Tractors. Our Ordnance equipment is required to be as light as possible and capable of rapid disassembly for air transport. Critical light alloys have been utilized in Ordnance, only when specific requirements have been laid down to make a weapon airborne. A notable example is the 105-mm Howitzer which was redesigned specifically to pass the doors of aircraft used by airborne troops. The weight of this gun was reduced from 4235 lb to 2500 lb, and the overall dimensions from 238 x 82 x 60 in. to 157 x 67 x 55 in. by using light alloys and developing a new carriage. Development of rocket and recoilless weapons is being greatly emphasized. This is important for future airborne operations, since it will be possible to deliver heavy, accurate fire with comparatively light equipment. Weight reduction and heavy armor do not go hand in hand unless revolutionary new discoveries are made in light-weight armor plate. In other words, considerable emphasis is already laid on weight and size reduction in the design of ground equipment, consistent with requirements for battlefield effectiveness, reliability, and low maintenance, and dependent on the availability of light metal alloys.

Undoubtedly, however, further advance can and will be made. Obviously, the airborne program will suffer if the entire burden of making the Army air-transportable is allowed to depend on the development of a large variety of cargo aircraft. As one possible approach to the problem, it is proposed that aircraft designers be utilized to redesign a few of those existing items of equipment, which it would be desirable to carry by air, but which fall outside of the weight or dimensional limitations of cargo aircraft which are planned for the near future. The possible gains from such a proposal may well not be phenominal. Perhaps some of the projects will result in weapons or equipment which do not meet battlefield requirements and cannot be used. However, there is bound to be some success and there will certainly be a valuable inflow of new ideas for the future, and a chance to evaluate them.

It is certain that future aircraft capacities cannot be tailored to carry all items of ground equipment with maximum efficiency. Some items are very large but comparatively light; others are compact but heavy. Compromises will have to be made some place. Tactical requirements dictate that as far as the initial phases of an airborne operation are concerned, aircraft characteristics will have to be compromised where necessary in favor of ground equipment. However, tactical requirements also dictate that the weight and dimensional characteristics of ground equipment needed during the final phases of an airborne operation be compromised in favor of keeping down the variety of different aircraft types required.

4. SUMMARY — This then is the program for the future:

a. An overall study of the problem to determine the several types and sizes of aircraft required to move the Army by air.

b. Positive coordination in addition to technical liaison to insure that the goal of air-transportability is eventually achieved for the entire Army without exception.

c. The design of standard ground equipment specifically for air movement, without compromise of battlefield requirements, to insure that the number of different aircraft types and sizes required can be kept down to a minimum.

If we develop the capability of moving and deploying our entire Army by air, we need never fear an attack which might come when our forces are in the wrong place at the wrong time.

CONCLUSIONS

1. Airborne operations will play a major part in the next war from the very beginning.

2. Every gun, transport vehicle, tank, tractor, and other item of equipment in the United States Army (naturally, with the exception of railway guns, heavy seacoast defense guns, and the like) must be air-transportable.

3. There is immediate need for an overall study of the weight and dimensional characteristics of every item of equipment in the army. Future troop carrier aircraft will be capable of efficient operation only if their weight carrying capacities and cargo compartment dimensions are based on such an overall study.

4. The number of different types and sizes of troop carrier aircraft developed must be kept down to a practical minimum. These aircraft must be designed around Army equipment so that they can carry efficiently the greatest possible number of different items.

5. The entire burden of making the Army air-transportable must not be allowed to fall solely on the aircraft designers. Items of Army equipment which cannot be carried by existing aircraft or by aircraft under development must be redesigned or new items, which are air-transportable, must be developed to take their place. This can be done and must be done without compromising battlefield requirements in any way.

6. The troop carrier aircraft and ground equipment development programs must be coordinated at frequent intervals by an agency charged with the specific responsibility of making the Army capable of movement by air. This agency should have the authority to require the development of new aircraft with new capacities; it should also have power to set limits on the reducible overall dimensions and weights of various categories and items of ground equipment, and to require the development of new items of ground equipment to replace items which cannot be carried by air.

7. The development of troop carrier aircraft capable of operating efficiently over the following distances, (with adequate fuel reserves), should be undertaken: 750 mile radius; 2500 mile range; 2500 mile radius. A study should be made to determine whether or not three distinct groups of aircraft are necessary. The operating distances given are based upon the present world-political situation. The question must be reconsidered periodically as the world-political situation changes.

8. Troop carrier aircraft must be capable of cruising at comparatively high speeds, while still retaining the ability to land and take off at safe, low speeds from small fields. Vigorous application of jet-assisted take off, boundary-layer control, high-lift devices, and deceleration devices can make this possible. Provision should be made for rapid installation of these devices on troop carrier aircraft, so that operation

in and out of small fields is possible when the aircraft are committed for use in an airborne operation.

9. Troop carrier airplanes must also be specially designed for rapid and easy loading and unloading of bulky items of ground equipment.

10. The development of gliders and glider-techniques must be continued since, at the present time, this is the safest, cheapest, most acceptable method of landing heavy equipment during the assault phase of an airborne operation. New glider developments should stress the following: adequate crash protection for crew and cargo; low landing speeds and use of deceleration devices for shortening the length of landing ground roll; rapid unloading through wide, rear-loading doors; adequate protection against small-arms fire for pilot and copilot; greater aerodynamic and structural efficiences through the use of high-lift devices and metal construction; and the use of assisted take-off techniques for decreasing the length of take-off run required by glider-towplane combinations.

11. New gliders (towed-aircraft) must be and can be easily designed for rapid conversion to low-powered transports. This will eliminate some of the major shortcomings of gliders, because ferrying to combat theatres and use as short-haul transports between airborne missions will be possible. The advantage of having such a transport, which can be easily and rapidly loaded and unloaded, for short-haul work immediately behind the lines, cannot be overemphasized.

12. Load capacities of future gliders should be based on the results of the overall study of Army equipment mentioned in paragraph 3 above, and should be increased only up to the point necessary to carry the largest item of Divisional equipment which might be needed initially in an airborne operation, before the time when it can be safely presumed that a suitable airstrip will be available for use. The sizes of new gliders should also be so controlled that troop-carrier airplanes in existence or under development can be satisfactorily used as towplanes.

13. Research should be continued to make possible and practicable glider towing operations under conditions of zero visibility.

14. The development of glider pick-up equipment should be continued to accommodate gliders up to and including the largest glider which is developed and accepted for operational use.

15. The following promising new techniques for the assault landing of heavy equipment should be developed and evaluated tactically: (a) assault transports; (b) the method of dropping heavy equipment by means of parachutes and decelerating rockets; (c) aircraft with jettisonable cargo compartments; and (d) rotary-wing aircraft.

16. Stable (non-oscillating) parachutes with lower opening loads must be developed for paratroopers.

17. There is a need for the development of a light, observation type airplane which can be carried or towed to the combat zone during an airborne operation. Consideration should also be given to the possibility of making this airplane roadable at moderate speeds.

18. Equipment and techniques should be developed to make possible very accurate, concentrated delivery of supplies by parachute in small areas.

AIR FORCE HISTORY AND MUSEUMS

[redacted]

[redacted]

16—64909-3 GPO