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The Condor A: New Soviet Heavy Transport

A Technical Intelligence Report

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SW 86-10015X
March 1986

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The Condor A: New Soviet Heavy Transport

A Technical Intelligence Report

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The Condor A: New Soviet Heavy Transport

Key Judgments

Information available as of 3 February 1986 was used in this report.

The Antonov AN-124 Condor A heavy transport (see figure 1) will significantly improve Soviet capabilities to deploy and supply forces rapidly outside the USSR. Its range and payload are much superior to those of the current Soviet heavy-lift military transport, the AN-22 Cock, and are somewhat superior to those of the [redacted] (see figure 2). Compared with Cock, Condor has nearly twice the payload and greater range. Range-payload performance of Condor and the [redacted] are almost identical for intermediate payloads, although Condor has a greater maximum payload and a longer range with relatively light payloads

Like Cock, Condor will be able to carry almost all types of vehicles and equipment used by Soviet ground forces. Condor's larger size will allow the Soviets to use fewer aircraft to transport a comparable payload to its destination. For example, an entire Soviet airborne battalion could be carried by four Condors; the same load would require at least 12 Cocks. While carrying this load, the four Condors or 12 Cocks could fly nonstop over 8,500 kilometers.

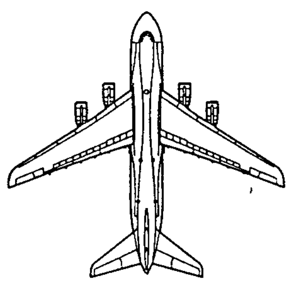
With its maximum payload of 150 metric tons, Condor can fly from Moscow to Kabul, Afghanistan, a distance of 3,300 kilometers. With a payload of about 125 metric tons, Condor can fly nonstop from Tashkent, USSR, to Hanoi without overflying China (4,700 kilometers). Condor can carry about 105 metric tons nonstop from Budapest to Luanda, Angola (6,300 kilometers), or over 50 metric tons nonstop from Moscow to Havana (9,600 kilometers). Condor's great range makes alternative flight routes feasible if countries along the direct flight routes deny the Soviets overflight permission.

[redacted] Condor [redacted] 1987 or 1988 and probably will supplement, and eventually replace, the existing fleet of 57 Cock transports in the heavy transport role. Our estimates of Soviet military requirements and production capabilities suggest the Soviets will have about 70 Condors deployed by 1995

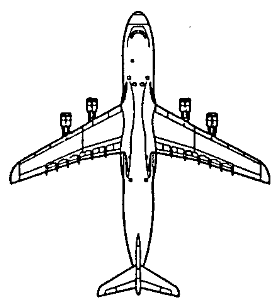
[redacted]

Figure 1
Comparative Overhead View of the Soviet AN-124 Condor and AN-22 Cock and the US C-5 Galaxy

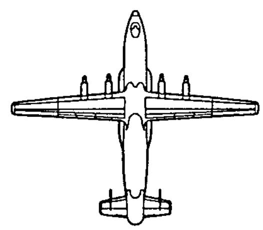
AN-124 Condor



C-5 Galaxy



AN-22 Cock



MIG-23 Flogger

T-72 tank

The Soviets claim Condor has a hybrid fly-by-wire/mechanical flight-control system. Mechanical flight-control links are undeniably present, but the presence of a fly-by-wire flight-control system in Condor cannot yet be confirmed.

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Contents

The Condor A: New Soviet Heavy Transport

Introduction

Condor A (figure 3) is the Air Standardization Coordinating Committee codename for the AN-124, a heavy military transport roughly equivalent in size and capability to the US C-5 Galaxy (figure 4). It was designed by the Antonov design bureau, which also designed the current Soviet heavy transport, the AN-22 Cock, and the AN-12 Cub medium tactical transport. Figure 5 shows weight comparisons of Condor, Cock, and the C-5B.

[redacted] According to public Soviet statements, however, the first flight of a Condor prototype took place on 26 December 1982. The prolonged prototype construction phase probably was a result of substantial delays in Soviet efforts to develop a large high-bypass-ratio turbofan engine to power Condor

The first Condor prototype [redacted] was first displayed publicly in the West in May and June of 1985 at the Paris Air Show. [redacted] and that true series production could begin within a year.

[redacted]

Our analysis of Condor is derived from engineering estimates based on information from several sources. A great deal of information was obtained during the public display of a Condor prototype at the 1985 Paris Air Show. Extensive photography of the display prototype and a large amount of information about the aircraft provided by the Soviets was of considerable value [redacted]

[redacted]

Technology Transfer

Airframe Design Technology

[redacted] Condor's configuration closely parallels that of the C-5, and the Soviets probably copied a number of lesser design features as well. Major similarities between the two aircraft include:

- High-mounted swept wing having nearly identical flap and slat configurations and having comparable spoiler arrangements.
- Four turbofan engines mounted on pylons under the wings.
- Two-deck fuselage arrangement, with a large lower cargo deck and a smaller upper passenger/crew deck.
- Full-width visor-type nose cargo door supplementing a full-width rear cargo door.
- Kneeling capability both for the main landing gear and for the nose gear.
- Size.

For Condor's airframe, we believe the extent of Soviet borrowing of ideas was limited to general design concepts and some design details. [redacted]

Although not strictly technology transfer, the borrowing of design features from a comparable aircraft—in this case, the C-5—probably saved the Soviets some time and effort during the design process. The level of research and development effort probably could be reduced by studying an effective, proven design and modifying it to suit their own needs. Furthermore, the Soviets might have been able to improve the design in some areas with knowledge gained by observing several years of testing and operations of the C-5.

Engine Technology

Although the United States has used large high-bypass-ratio engines operationally since the late 1960s, the Soviets have been unable to develop such an engine until recently. [redacted]

[redacted]. Open sources, such as NASA reports and international conferences, were almost certainly used by the Soviets during the development of the D-18T. We believe that the design and development of the D-18T could have been helped considerably by using these sources.

[redacted]

Production Technology

Technical Characteristics

Airframe

Description and Special Features. General. Figure 6 shows the general arrangement of the Condor A aircraft. The similarities—in both size and general arrangement—of Condor and the C-5 are illustrated in figure 7. Although a number of differences in detail can be seen, the only observed major external differences between the designs of Condor and the C-5 are the tail geometry and the landing gear configuration. As shown in figures 3 and 4, the horizontal tail of Condor is fuselage mounted, while the C-5 has a T-tail. Figure 8 shows the difference between Condor's 20-tire, 10-strut main landing gear arrangement and the C-5's 24-tire, four-strut configuration

In terms of aerodynamics, Condor and the C-5 are essentially comparable. The wing planform area of Condor is about 645 square meters. This is approximately 12 percent greater than that of the C-5. The wing leading edge sweep of Condor is about 31 degrees, compared to about 28 degrees for the C-5. The thickness-to-chord ratio of Condor's wing also appears to be somewhat greater than that of the C-5. The high-lift devices—used to change the shape and characteristics of the wing for optimum takeoff and landing performance—are nearly identical to those of the C-5. Condor's high-lift devices include trailing

Figure 6
Three-View Drawing of Condor

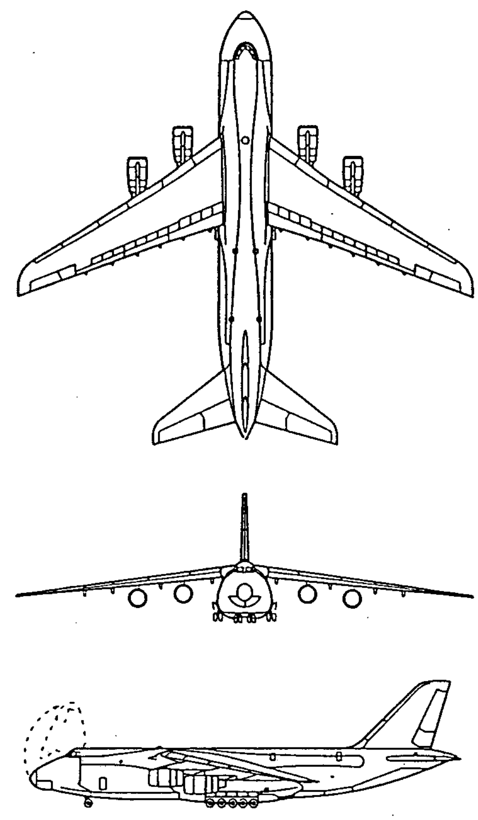


Figure 7
Overhead Comparison of Configuration Similarities of Condor and the C-5

AN-124 Condor

C-5 Galaxy

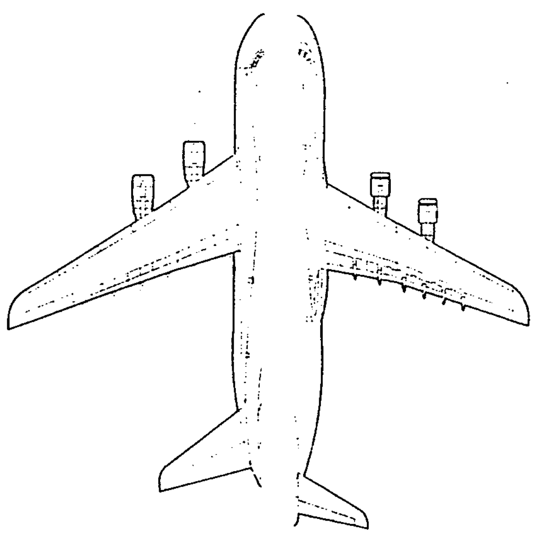
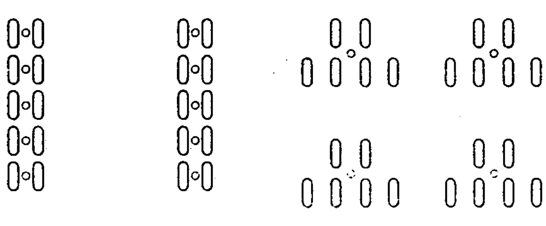


Figure 8
Condor and the C-5 Main Landing Gear Arrangement

AN-124 Condor

C-5 Galaxy



edge single-slotted Fowler flaps [1] over about 70 percent of the span and full-span leading edge slats.

Condor is also fitted with 12 spoiler segments on the upper surface of each wing (24 segments in all). These spoiler segments are slightly different in arrangement than those of the C-5, but the two arrangements are functionally the same. Condor's 16 inboard segments are used for lift dumping to reduce the landing distance and possibly as airbrakes for descent path control as well. The eight outboard spoiler segments are used in concert with the split (two-segment) ailerons to provide roll control power. The rudder and elevators are also split into two segments, like the C-5's. The two-segment control surfaces probably are for redundancy and reliability, giving the aircraft a fail-operative control system should one or more hydraulic systems fail [redacted]

[redacted] Condor's wing uses a supercritical [redacted] Analysis of photography of Condor's wing taken at the Paris Air Show suggests that Condor's wing is not a supercritical design because features characteristic of typical supercritical sections are not evident. Second, Condor's cruise speed, as claimed by the Soviets, is close to that of the C-5. We would expect a "supercritical Condor" to fly at a cruise speed distinctly higher than that of the C-5. Third, the use of a supercritical airfoil would practically guarantee some publicity by the Soviets about such a relatively advanced feature. No such publicity has been noted. The advantage of using a supercritical section is that a higher cruise speed can be achieved without decreasing the wing thickness ratio or increasing the wing sweep. Alternatively, one can increase the wing thickness ratio or decrease the wing sweep without sacrificing cruise speed. A thicker wing has more internal volume for fuel and would be a lighter wing, because a thicker wing is more efficient structurally. Decreasing the wing sweep would also save weight.

[1] A plain trailing edge flap deflects downward to increase lift, while a Fowler flap moves aft and deflects downward. A Fowler flap is generally more effective than a plain flap.

Condor was designed with a visor-type nose cargo door and ramp (figure 9) similar in principle to that on the C-5. Condor is the first Soviet aircraft so equipped. The nose cargo door permits more rapid vehicle and cargo loading and unloading. The "drive-through" capability allows vehicles to enter and exit the aircraft through the nose and tail. Similarly, the nose and tail cargo doors allow cargo to be loaded or unloaded from both ends simultaneously. The front and rear ramps are the same width as the main cargo floor. Figures 10 and 11 show how the cargo doors and ramps operate.

[redacted] Furthermore, we believe that this is little or no disadvantage for what is essentially a strategic, not tactical, airlifter. There is very little need for a heavy airdrop capability in Condor, because any cargo or vehicle light enough to be airdropped could be dropped by tactical transports such as the AN-12 Cub and IL-76 Candid. By comparison to these smaller transports, Condor would be a more vulnerable and more lucrative target over a drop zone.

We do not believe that heavy platform-mounted cargo (perhaps 1,000 kilograms and over) or vehicles can be airdropped through Condor's rear cargo doors using the conventional method of floor- and ramp-mounted rollers. This is because the aft pressure bulkhead, which doubles as the second section of the cargo ramp, appears to be permanently attached to the first ramp section at the hinge line (see figure 11). It is highly unlikely that the ramp can fully unfold in flight, thus the pressure bulkhead is an immobile obstacle preventing the use of the ramp for dropping heavy cargo. [redacted]

It is possible, but not probable, that Condor was designed to be able to airdrop heavy cargo by using the cargo bay's rail-mounted overhead crane system,

[redacted]

which is described below in the section entitled "Internal Arrangement." We base this belief on our assessment that, for airdrop purposes, the conventional floor roller method would require less special equipment, would deploy payloads more reliably, and would be easier and safer to use, and thus would be the preferred method if a heavy airdrop capability were desired. We conclude that airdrop of heavy equipment and vehicles was not a design requirement for Condor. Should the need arise, paratroopers and light cargo bundles, up to perhaps 1,000 kg, probably could be dropped through Condor's rear cargo doors.

[redacted] Furthermore, the presence of the nose cargo door complicates the installation of a receiver probe. This is because the

The other major type of aerial refueling, the boom-receptacle method, is not used at all by the Soviets. The boom-receptacle method is the standard method for US Air Force aircraft, including the C-5.

probe must be placed in a location that will not interfere with the ground operation of the nose visor. In addition, the receiver probe should be easily visible to both pilots and should be close enough to the cockpit that judging distances between the probe and drogue is not difficult. Thus, placing the probe away from the nose visor probably would make probe-drogue hookups very difficult. In any case, the "bow wave" of an aircraft as large as Condor would markedly hinder probe-drogue hookups

Internal Arrangement. Figure 12 shows the internal arrangement of Condor. Condor was designed with a double-lobed fuselage cross section, [redacted] This design results in a large, low-to-the-ground main deck for cargo or troops in the lower lobe of the fuselage and a smaller deck for the flightcrew and troops in the upper lobe. Two folding access ladders, one forward and one aft, provide access between Condor's cargo deck and the upper deck.

The upper deck is split into a forward and an aft section by the wing carry-through structure. The forward upper deck area includes the cockpit and space for a crew rest area and passenger seats for a relief crew, couriers, VIPs, or troops. The aftmost area of the forward upper deck probably houses the aircraft's air-conditioning and pressurization systems. Figure 13 shows a hypothetical 21-passenger layout, based on the space available, for the forward upper deck. In this layout, a crew rest area was not fitted in order to fit more passenger seats.

The aft upper deck, which would not be used to carry cargo, provides enough space to carry 80 to 90 troops. Figure 14 shows a hypothetical 88-passenger arrangement for the aft upper deck. There is no direct access between the forward and aft upper decks, except possibly for an emergency tunnel through the wing carry-through area.

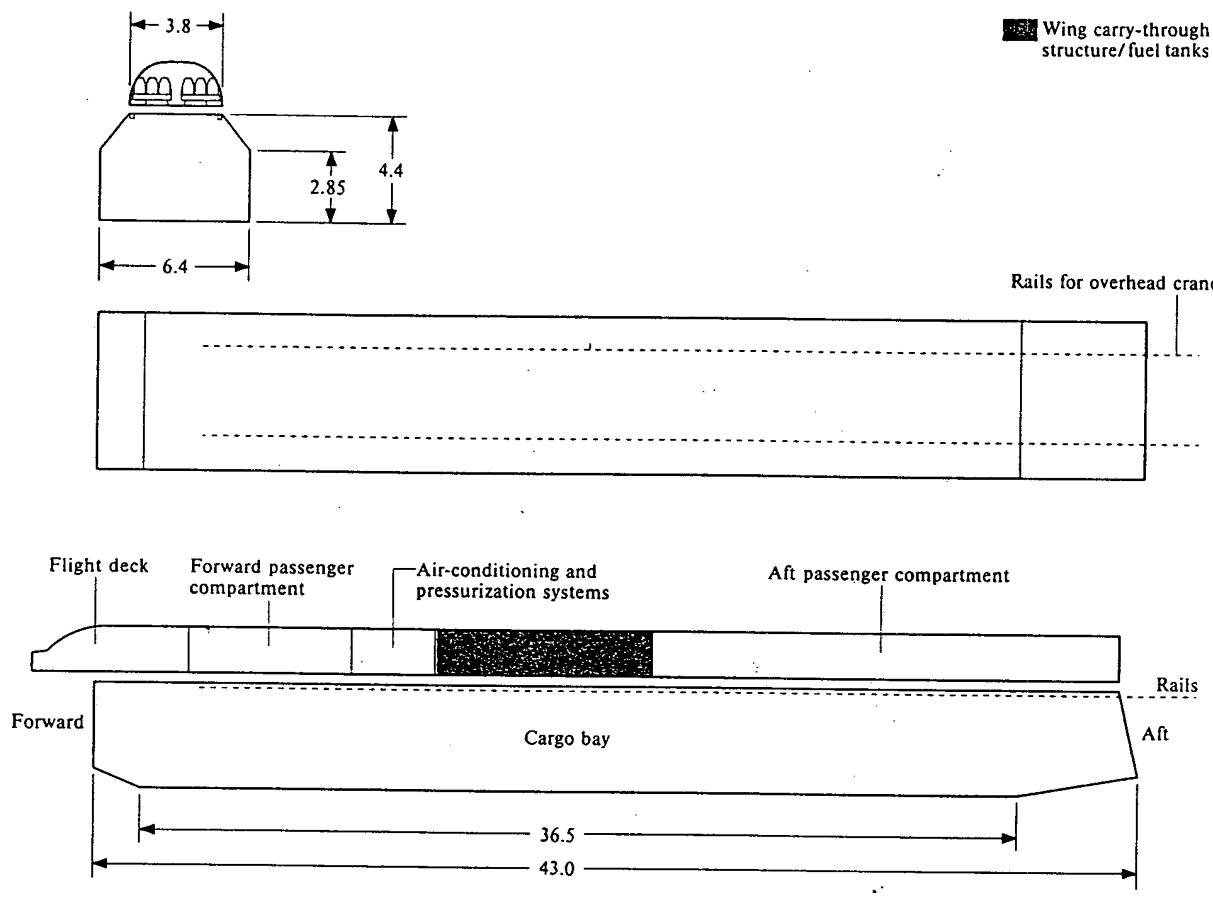
As shown in figure 12, the cargo bay is about 36.5 meters long (not counting the ramps), 6.4 meters wide, and 4.4 meters tall. A relatively light cargo load probably can be carried on the inboard portions of the loading ramps, which would slightly increase the usable length of the cargo bay. For cargo loading and positioning, two 10,000-kg-capacity overhead traveling cranes are mounted transversely on two overhead rails and can travel the length of the cargo compartment. Each crane has two 5,000-kg-capacity electric hoists.

The cargo floor of the aircraft displayed at the Paris Air Show did not have a roller system for loading cargo. With the overhead cranes installed, the lack of a floor roller system probably is not a significant limitation. The entire cargo floor and the inboard sections of the loading ramps reportedly can be fitted with removable tiedown fittings for securing cargo.

Compared with Cock, Condor's cargo deck is over a third longer (36.5 versus 26.4 meters) and nearly half again as wide (6.4 versus 4.4 meters). The height of the cargo bays is nominally the same for the two aircraft, although Cock's curved cargo bay ceiling actually has a slightly higher peak height. Cock has only a single deck, however, and reportedly carries only 28 passengers outside the cargo bay

Although Cock already can carry almost all types of equipment used in the Soviet ground forces, the much larger Condor will be able to carry more equipment per sortie. The 150-metric-ton maximum payload permits Condor to carry up to three Soviet main battle tanks such as the T-72. The great width of the cargo deck permits two-abreast loading of vehicles less than about 3.0 meters wide, which includes most trucks and towed artillery and some light-armored vehicles. This is a significant advantage over the

Figure 12
General Internal Arrangement of Condor



All dimensions in meters

Cock, which cannot load vehicles two abreast unless they are less than about 1.9 meters wide—roughly jeep sized. Jeeps or other vehicles less than about 1.9 meters wide could be carried three abreast on Condor's cargo deck. Such dense loadings help ensure that a relatively heavy payload can be loaded on a Condor before running out of space on the cargo deck. The troop seats on Condor's aft upper deck allow the vehicle crews to accompany their vehicles

The upper and lower decks are pressurized independently, and the access hatches between the two decks are equipped with pressure seals. Soviet statements indicate that the differential pressure is about 0.55 atmosphere on the upper deck and about 0.25 atmosphere on the cargo deck. At nominal cruise altitudes of 10 to 12 kilometers, the cabin altitude would be

Figure 13
Forward Upper Deck Arrangement

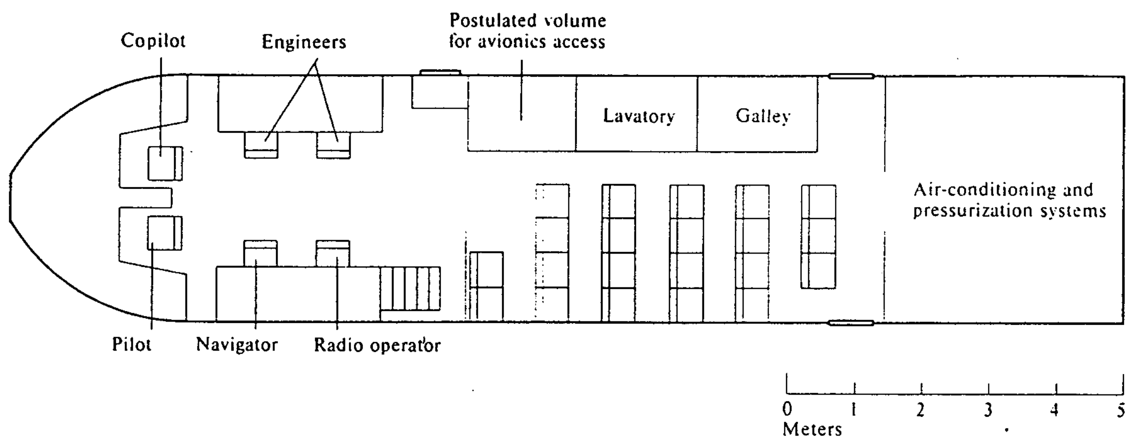
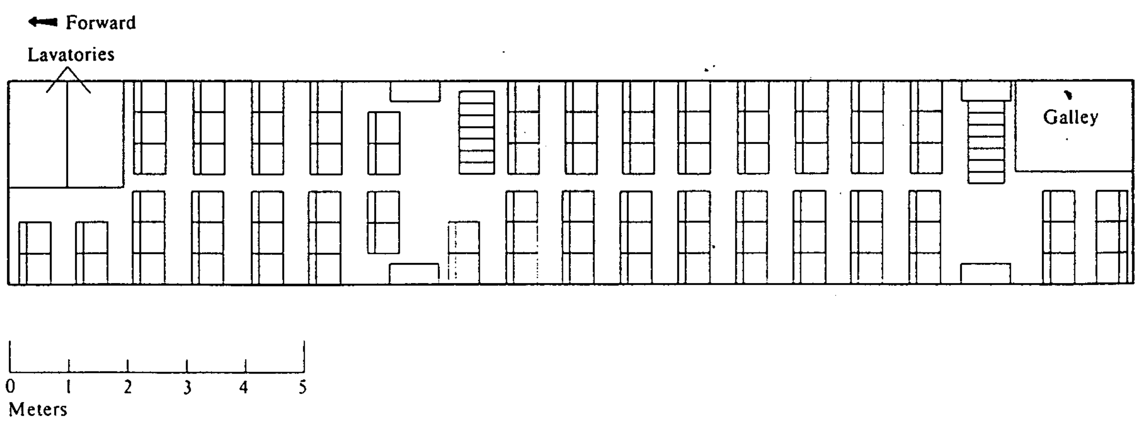


Figure 14
Hypothetical Passenger Seating Arrangement
for Aft Upper Deck



equivalent to about 1,700 to 2,500 meters on the upper deck and about 5,300 to 6,400 meters on the cargo deck. The cargo deck can also be left unpressurized.

Although the upper deck pressurization is comparable to that of the C-5, the cargo deck pressurization is much lower. An advantage of the lower pressure is that the structural weight of the fuselage can be reduced somewhat. A second advantage is that less engine bleed air is required for pressurization, resulting in lower engine specific fuel consumption.

The disadvantage of the low cargo deck pressurization level is that it results in a relatively high equivalent cabin altitude, making it impractical to carry troops on the cargo deck. The high equivalent cabin altitude results in a very low oxygen content in the cabin air that would cause adverse physiological effects to passengers [3] on the cargo deck. These debilitating (but not fatal) physiological effects could be eliminated by flying at a lower altitude, but the range of the aircraft would suffer accordingly. Alternatively, the passengers on the cargo deck could be supplied with oxygen bottles and masks. The passengers on the cargo deck also might have to wear cold-weather gear, depending on the design specifications and capabilities of Condor's environmental control system. We have no information about such specifications.

We believe the low cargo deck pressurization indicates that Condor was not intended to carry troops on this deck in normal operations. We do not consider this to be a major limitation, however, since as many as 90 troops can be carried on the upper deck. Furthermore, a cargo bay the size of Condor's is so uniquely valuable for transporting vehicles and heavy equipment that we would not expect it to be used to carry troops except in unusual circumstances. If only troops and personal equipment were to be carried, the Soviets would find it less extravagant to use any of the other 2,000 or more medium- and long-range transports (including airliners) in Military Transport Aviation (VTA) and Aeroflot.

[3] Troops acclimated to high altitudes (as distinct from troops that are merely physically fit) would suffer little or no adverse effects. However, troops fitting this description would be uncommon. (C NF)

In the unlikely event that the Soviets decide to carry troops on both decks, palletized troop seats could be fitted to carry 300 to 400 troops on the cargo deck, depending on how tightly the Soviets are willing to pack their troops. With troops on both decks, maximum troop capacity would be roughly 400 to 500 troops.

Landing Gear. The main landing gear of Condor (figure 15) consists of 20 wheels on 10 struts. Five struts, with two wheels per strut, are mounted in tandem on each side of the fuselage. Although a C-5–style main landing gear arrangement is superior for operations from soft fields or light-duty runways because of its softer "footprint," Condor's gear arrangement may be somewhat lighter and more compact.

The wheels on the first (front) main gear strut on each side are believed to be steerable to facilitate ground handling. The wheels on the fifth (rear) main gear strut are castered; that is, they will swivel to trail the forward wheels during ground turns. The Soviets claim that Condor, like the C-5, can be turned around 180 degrees on a 46-meter-wide (150-foot-wide) runway. We believe this claim is accurate.

The nose landing gear (figure 16) consists of two struts side by side, with two wheels per strut. The Soviets claimed the unusual two-strut arrangement was lighter than a single strut having four wheels such as the C-5 has. The wheels on both nose struts are steerable 68 degrees left or right for ground maneuvering.

Condor's landing gear is able to "kneel" much like that of the C-5. The height of Condor's kneeling landing gear can be reduced while the aircraft is on the ground to bring the belly of the aircraft lower to the ground. This decreases the angle between the loading ramps and the ground and makes it easier to load unusually long or bulky cargo or vehicles. The landing gear reportedly is able to kneel and rise when Condor is carrying its maximum payload and an unspecified fuel load. Thus Condor probably can kneel and rise at a gross weight of at least 330 metric tons (loaded with its maximum payload but no fuel) and possibly as much as 405 metric tons, its maximum takeoff weight.

Figures 17 and 18 illustrate how Condor's landing gear is designed to kneel. For forward kneeling (figure 17), the visor is first raised, then the nose gear struts begin to pivot to bring the nose wheels forward and upward. While the nose struts are still pivoting, support jacks are extended to support the nose of the aircraft. The nose struts continue to pivot until they are horizontal, bringing the nose wheels forward and upward. When fully kneeled, the forward fuselage is 1.2 to 1.3 meters lower than normal, the aircraft is in a slight (3.5 to 4 degree) nose-down attitude, and the forward loading ramp can be extended.

For aft kneeling (figure 18), the main gear struts compress at least 0.3 meter to lower the aft fuselage, which lowers the rear cargo door sill by about half a meter. Reportedly, both the nose and main gear can kneel simultaneously to bring the aircraft to a "level kneeled" position

[redacted]

Condor has a higher gross weight, fewer tires, and a higher tire pressure than the C-5 and will have poorer landing gear flotation.[4] Condor should be able to operate from most permanent nonsod runways without damaging the runway surface. For operations from light-duty runways, however, the aircraft may be required to operate at a reduced gross weight to prevent damage to the runway. [redacted]

[4] High flotation means the landing gear effectively spreads the weight of the aircraft over a greater area of the runway than does a low-flotation landing gear. A high-flotation gear enables the aircraft to use a runway with thinner pavement and/or a softer surface (such as sod) than does landing gear with lower flotation

[redacted] Condor can routinely operate from unprepared strips on frozen swamps and lakes.[5] However, Condor's landing gear probably would cause severe rutting on unfrozen sod runways. Therefore, we expect that Condor would not use unfrozen sod runways except in emergencies.

Weights. At the 1985 Paris Air Show, the Soviets claimed Condor has a 405-metric-ton (405,000-kg) maximum takeoff weight and a design load factor limit of 2.3 G's.[6] These are reasonable values, given maximum takeoff weights of 349 metric tons for the C-5A and 380 metric tons for the C-5B, with a limit load factor of 2.25 G's. Overload gross weights of perhaps 440 metric tons may be possible if Condor is restricted to a maneuver load factor of 2.0 G's or less.

With a 405-metric-ton takeoff weight and a 2.3-G load factor limit, we calculate that the operating weight empty of Condor is about 180 metric tons. This weight is based on our assessment that Condor has a predominantly conventional aluminum structure, with roughly 4 percent of the structural weight composed of composite materials. Table 1 gives a more complete weight breakdown of Condor. At a nominal maximum takeoff weight of 405 metric tons, subtracting the 180-metric-ton operating weight empty yields a maximum useful load (fuel plus payload) of 225 metric tons.

The Soviets have stated that the maximum payload of Condor is 150 metric tons, or 15 ten-metric-ton sections of palletized cargo. This maximum payload is

[5] As a ballpark figure, a fully loaded Condor would require about a 2-meter thickness of freshwater ice to support its weight. Ice of this thickness probably could be found only on arctic lakes that are frozen for all or most of the year. For landing [illegible] ice, the thickness of ice required will roughly double

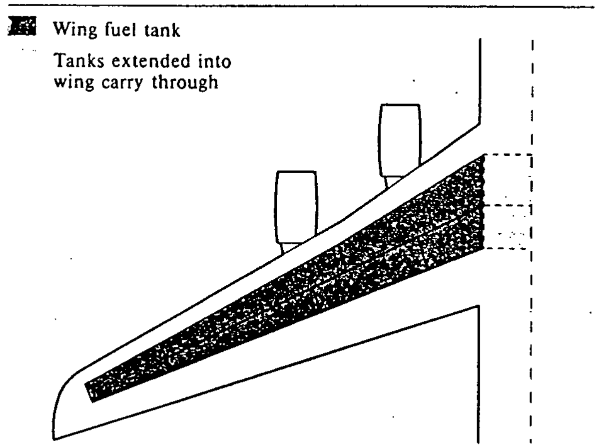
[6] An aircraft's load factor, expressed in G's, is equal to the total lift generated by the aircraft divided by the aircraft's weight. For an aircraft that is flying straight and level, the load factor is equal to 1.0 G. The load factor is greater than 1.0 G when the aircraft is turning or pulling up into a climb and is less than 1.0 G during a pushover into a dive.

Table 1
Condor Weights Breakdown *Metric tons*

Airframe group	131	
Propulsion group	23	
Fixed equipment group	23	
Crew and operational items	3	
Operating weight empty	**180**	
	Ferry Mission [a]	Maximum Payload Mission
Operating weight empty	180	180
Fuel weight	225	75
Payload	0	150
Takeoff weight	**405**	**405**

[a] For a ferry mission, the aircraft carries no payload and a full fuel load.

Figure 19
Estimated Fuel Tank Locations



about 37 percent of the aircraft's maximum takeoff weight with the nominal maximum payload (118-metric-ton maximum payload and 380-metric-ton maximum takeoff weight at a 2.25-G load factor). limit. Thus, Condor's maximum payload fraction of 37 percent is comparable to that originally intended for the C-5.

Photographs of Condor from the 1985 Paris Air Show suggest that the aircraft has 14 fuel tanks located in the wing and probably extending into the wing carry-through structure. Figure 19 shows the estimated fuel tank configuration. No fuel is assessed to be carried in the fuselage, as the volume available for fuel in the wings and wing carry-through structure alone permits 240 metric tons or more of fuel to be carried. A 240-metric-ton fuel load would cause the aircraft to exceed its 405-metric-ton maximum takeoff weight, even if no payload were carried.

The calculated fuel volume available with the configuration in figure 19 is about 240,000 liters in the wings alone, plus at least 70,000 liters more if the fuel tanks extend into and fill the wing carry-through structure. Thus the total volume available for fuel for the wing plus wing carry through is roughly 310,000 liters. Using TS-1 fuel [7] with a density of 0.775 kg/liter, the corresponding fuel weights are about 185 metric tons for the wing alone and 240 metric tons for the wing plus wing carry through. If the denser T-1 fuel is used, these fuel weights increase to about 195 metric tons for the wings alone and 255 metric tons

[7] Markings on the Condor prototype at the 1985 Paris Air Show indicate that the aircraft's engines can use either TS-1 or T-1 fuel.

for the wing plus wing carry through. However, maximum fuel load is not likely to exceed about 225 metric tons. With an operating weight empty of about 180 metric tons, a fuel load of over 225 metric tons would cause the aircraft to exceed its normal maximum takeoff weight of 405 metric tons. Therefore, the maximum fuel load of the aircraft is limited by weight and not by available volume.

All range-payload computations in this report assume that Condor's maximum fuel weight is 225 metric tons, which requires that fuel tanks extend into the wing carry-through structure. Photography of the underside of the wing carry-through structure, which is visible from inside the cargo bay, suggests that this is a valid assumption. The very high ferry range for Condor claimed by the Soviets—16,500 kilometers (km)—also suggests that the aircraft is equipped with fuel tanks in the wing carry through [redacted]

Condor's maximum fuel weight would be roughly 185 to 195 metric tons without wing carry-through tanks. With payloads of less than 30 or 40 metric tons, the absence of wing carry-through tanks would result in a slight reduction in our range estimate. Without carry-through tanks, the fuel load is limited by the maximum takeoff weight of the aircraft, not by the available fuel volume, for payloads of over 30 to 40 metric tons. Thus, for payloads of 30 to 40 metric tons or more, there would be no reduction in our estimate of Condor's range if in fact the aircraft does not have wing carry-through tanks.

Composites Usage. Condor is assessed to be constructed primarily of aluminum alloys and lesser amounts of steel and titanium alloys, with roughly 4 percent of the structural weight of the aircraft being composite materials. This assessment is based on Soviet claims of composites usage for Condor and on previous Soviet practice for transport aircraft. Data provided by the Soviets show that composites usage is limited to non-flight-critical components

[redacted]

A Soviet display on composite materials at the 1985 Paris Air Show indicated the location of composite components on Condor (figure 20). Some photography of Condor at this air show is good enough to distinguish between metal and composite parts. These photographs indicate that this display probably is accurate. Graphite-epoxy composites were used for the landing gear doors, flap track fairings, aft clamshell doors, engine pylon skin, wing root fairing, and parts of the wing-fuselage fairing. Graphite-epoxy was also used for many of the access doors in the wings and empennage. Organic fiber or glass fiber composites were used for the engine cowlings, flap track fairings, nose and tail radomes, main landing gear fairing, engine pylon skin, wing root fairing, and parts of the wing-fuselage fairing. According to the Soviets, composite components make up 1,500 square meters of Condor's exposed surface are

Figure 20 also shows the Soviet claim that Condor has about 5,500 kg of composite materials in the airframe. The amount of composites claimed to be used is about 4 percent of the structural weight of the aircraft. According to the display, 2,500 kg of graphite-epoxy composites and 3,000 kg of glass fiber and organic fiber composites were used, resulting in a weight savings of 1,800 kg relative to metal components. The breakdown between glass fiber and organic fiber (for example, aramid fibers such as Kevlar) composites was not further defined

[redacted]

The claimed weight savings amounts to a reduction of about 25 percent relative to metal components. This percentage is typical of weight savings demonstrated on Western aircraft using components made of advanced composites such as carbon-epoxy or Kevlar-epoxy.

Although not indicated on the placard, graphite-epoxy appears to have been used to reinforce aluminum transverse beams on the ceiling of the cargo bay (figure 21). Many of these beams appear to have a graphite-epoxy stiffener, running the length of the beam, bonded to the lower flange and probably to the upper flange as well. A Soviet composites engineer claims this stiffener results in a weight savings of 12 to 15 percent compared to an unstiffened aluminum beam.

The degree of composites usage claimed by the Soviets is comparable to that of current-generation Western transport aircraft such as the Boeing 767 or the McDonnell Douglas C-17. The relatively low composites percentage for the 767 and C-17 (compared to Western state of the art) reflects a conservative approach to composites. On the basis of the similar conservatism typically shown in Soviet aircraft design, we believe the low composites usage on Condor is due to conservative design. Thus Condor may not accurately reflect the Soviet state of the art in composites.

In general, composite components can reduce both structural weight and production costs by 20 percent or more per component. However, the reduction in

[redacted]

Condor's overall structural weight because of composites is small because the percentage of composites usage is relatively small. Because the weight reduction is small, the performance improvement will be correspondingly small. Thus the incorporation of composites into Condor confers only a slim advantage, if any, relative to the C-5's all-metal construction

The weight reduction claimed by the Soviets is of the same order of magnitude as the accuracy range of our weight estimate, which is on the order of 10 metric tons.

Propulsion

General. Condor is powered by four Lotarev D-18T high-bypass-ratio turbofan engines (figure 22). [redacted] Consequently, we judge that the D-18T is somewhat behind the US state of the art for this class of engine

Some features of the D-18T, such as the active clearance control feature described below, are relatively new developments in the West as well as in the USSR. Also, the performance of the compressor section of Soviet engines historically has been slightly superior to that of US engines. However, overall, and in the specific areas of durability and turbine inlet temperature, we judge the D-18T to be behind Western technology. Because other variables may drive the design of an engine, we cannot judge whether the D-18T represents the absolute limit of Soviet technology for this class of engine. These other variables might be a desire to reduce the cost or increase the life of an engine, both of which may lead to reducing the engine's performance. The performance claimed by the Soviets may take into account such performance reductions or the claims may be overly optimistic and thus subject to degradation because of, for example, a desire to increase the engine's life.

Engine Description and Performance. Unlike most Western high-bypass-ratio turbofans, the D-18T is a three-spool turbofan. Soviet statements indicate that the D-18T has a single-stage fan driven by a four-stage uncooled turbine. The intermediate spool and the high-pressure spool each have seven compressor stages and a single-stage cooled turbine.

In a major Western aerospace magazine, a Lotarev design engineer stated that the D-18T uses active clearance control on the turbine casing. Photography of the D-18T on display at the Paris Air Show independently supports this claim. Active clearance control increases turbine efficiency and reduces specific fuel consumption by precisely controlled cooling of the turbine casing. The controlled cooling regulates the diameter of the casing and thus controls the clearance between the tips of the turbine blades and the casing. An electronic control unit regulates this clearance to maintain optimum engine performance in all flight regimes. The technique of active clearance control has been used on several models of Western engines within the last five years

The Soviets have stated that the first 11 compressor stages have titanium blades and the last three have either nickel or steel blades. All compressor stators were said to be made of steel. The fan stators are claimed to be of composite material, which would help reduce the weight of the engine. Reportedly, the only variable geometry in the compressor is in the guide vanes to the first stage in the intermediate compressor to make starting easier

Table 2
Characteristics of the Lotarev D-18T Engine

Dry weight	4,100 kg
Fan diameter	2.33 meters
Maximum turbine inlet temperature	At least 1,600 degrees Kelvin (1,327 degrees Celsius)
Overall pressure ratio	27.5 [a]
Bypass ratio	5.7 [a]
Uninstalled performance	
Sea-level static, ISA [b] + 13 degrees Celsius	
Thrust	23,430 kg
SFC (Soviet claim)	0.36 kg/kg/hr [c]
[ ]	
Mach 0.75, 11 km, ISA	
Thrust	4,680 kg
SFC (Soviet claim)	0.57 kg/kg/hr
[ ]	
Engine life (goal)	18,000 to 20,000 hours with three overhauls

[a] At Mach 0.75, 11,000-meter altitude.
[b] ISA = International Standard Atmosphere.
[c] Kilograms of fuel burned per hour per kilogram of thrust.

The Soviets claim that the D-18T has a sea-level static thrust (uninstalled) of about 23,400 kg, flat-rated [8] to 28 degrees Celsius. Other characteristics, obtained from a Soviet brochure on the D-18T, are shown in table 2. Considering the Soviets' lack of experience with large high-bypass-ratio turbofans, the Soviet claims for specific fuel consumption (SFC) shown in table 2 are probably optimistic, since the values quoted are near the US state of the art. Our estimates of the probable SFC for the engine, obtained with the aid of a detailed engine cycle analysis based on turbine inlet temperature, bypass ratio, and other information on the D-18T published by the Soviets, seem more reasonable.

[8] Flat-rating is when the thrust of an engine is limited below a given ambient temperature even though the engine is capable of more thrust when the ambient temperature drops. Thus the engine produces a nearly constant, predictable thrust for a wide range of ambient temperatures

On the basis of the low (by Western standards) design lifetimes of previous Soviet engines and on the relatively small foundation of Soviet experience with high-bypass-ratio engines, we believe that the actual lifetime of current versions of the D-18T is substantially lower than the claimed goal of 18,000 to 20,000 hours.

As installed on Condor, the D-18T is equipped with a thrust reverser that is mounted on the fan duct. When the thrust reverser is activated, a section of the fan cowling translates aft on rails to expose the thrust reverser. Blocker doors then deflect into the fan airflow to redirect the airflow through the thrust reverser cascades. The thrust reverser reverses the fan airflow but not the core airflow.

Auxiliary Power Units. To provide power for the aircraft's systems when the main engines are shut down, two auxiliary power units (APUs) are installed. One APU is inside each main landing gear fairing aft of the rearmost main gear strut (see figure 10). The APUs can be operated in the air or on the ground.

Flight Controls and Avionics

Fly-By-Wire Flight-Control System. The Soviets claim Condor has a quadruplex fly-by-wire (FBW) flight-control system, with mechanical backups for the primary flight controls. According to at least one open-source report, the mechanical pitch axis backup has a limited authority due to high control forces. Some sources quote the Soviets as saying that the FBW system has an emergency fifth channel, apparently consisting of a direct electrical link to the control servos, bypassing the flight-control computers. Soviet claims regarding the type of FBW system used are contradictory—they have claimed that the system is both analog and digital. As Condor is the first Antonov aircraft claimed to have a FBW flight-control system, the system probably is the less advanced analog type

In a true FBW system, the pilot's control inputs and data from velocity, acceleration, and position sensors on the aircraft are interpreted by a flight-control computer. The flight-control computer then commands the control surfaces to produce the desired aircraft response. Advantages of FBW flight-control systems include "carefree maneuvering" and, for large aircraft, a lighter weight control system. Carefree maneuvering is where the flight-control computer is programed to prevent the aircraft from exceeding structural or aerodynamic limits regardless of pilot commands to the contrary. This allows the pilot to concentrate on flying without worrying about damaging the aircraft by inadvertently exceeding the aircraft's limits.

An aircraft with a true FBW system can be—but is not required to be—aerodynamically unstable, because the flight-control system can be programed to actively stabilize the aircraft. The advantage of an unstable aircraft is that it can be designed to be a few percent more efficient aerodynamically than a comparable stable aircraft by allowing a reduction in trim drag

A mechanical control system undeniably was present on the prototype displayed at the Paris Air Show. We believe mechanical control links exist to all primary flight-control surfaces. However, without further information, the existence or absence of FBW channels in the flight-control system cannot be confirmed. Based in part on the fact that Condor has a mechanical (manual) mode in the flight-control system, we are almost certain that Condor was not designed to be aerodynamically unstable.

Soviet claims imply that Condor has a full three-axis FBW flight-control system with a mechanical backup. On the basis of FBW development history in the West, we believe it is more likely that some (but not all) control surfaces have FBW controls. Less probable is a full three-axis FBW system having complete mechanical redundancy to the primary control surfaces. A worst case third possibility is that no true fly-by-wire system is fitted at all. Given these three possibilities, we believe that FBW technology at the Antonov design bureau is at best on a par with Western technology and at worst five to 10 years behind.

The full advantages of pure FBW operation cannot be realized in Condor because of the mechanical backup system. Thus we believe that the incorporation of

FBW technology into Condor does not confer any performance improvement.

Cockpit Displays and Controls. Cockpit instruments are conventional needle gauges and vertical tape instruments not markedly different from the type of instrumentation on the C-5. No electronic flight displays, such as those found on state-of-the-art Western transports, are used. Conventional control yokes are used, although the Soviets reportedly considered using side-stick controllers. Side-stick controllers are more consistent with a pure FBW system rather than a mixed mechanical/FBW system such as in Condor.

The cockpit is arranged for a flightcrew of six: pilot, copilot, two flight engineers, navigator, and radio operator. This "people-intensive" philosophy is in marked contrast to the standard three-man C-5B crew and to the two-man crew of newer Western transports such as the Boeing 767 and the C-17.

Electronics [redacted] The Soviets have indicated that Condor has at least two radars; one is used primarily as a weather radar and the other as a ground mapping/navigation radar. The radome in the nose of Condor is arranged to accommodate one radar (probably the weather radar) antenna in the center of the nose and a second antenna in a "chin" radome below and aft of the first. The chin radome probably houses the ground mapping/navigation radar.

Information from open sources and from [redacted] observers at the 1985 Paris Air Show indicates that navigation systems on Condor include three, possibly four, inertial navigation units; radio navigation gear (possibly including Omega); and an astrocompass. A hemispherical radome on top of the fuselage (figure 23) may contain an antenna for a satellite navigation receiver, although the Soviets deny that Condor has such a system. A second and less likely possibility is that the radome conceals a satellite communications antenna.

[redacted]

A large aft-facing radome on Condor's tailcone (figure 24) may be intended to house antennas for radar warning and electronic countermeasures (ECM) gear. Other possible gear concealed by the radome could be a rendezvous/station-keeping transmitter or, less probable, an aft-looking search radar

Other electronics carried on Condor, such as communications equipment, are not expected to differ significantly from other Soviet military transports such as the IL-76 Candid or AN-22 Cock.

Performance

Range and Payload. In terms of range-payload performance, Condor represents a significant improvement over the current Soviet heavy military transport, the AN-22 Cock. Condor outperforms the C-5B for payloads of over 120 metric tons or under 50 metric tons. Figure 2 compares our assessment of the range-payload performance of Condor with that of the C-5B and Cock. Figure 25 shows Condor's ground coverage from Moscow when operating with different payloads.

Cruise Speed Improvement. Besides having much better range-payload performance than Cock, Condor will fly at significantly higher cruise speeds than Cock. Cock cruises at roughly 350 knots, while Condor cruises at roughly 450 knots, almost 30 percent faster. These figures are based on Soviet claims and on engineering analysis of the two aircraft. The higher cruise speed of Condor results in shorter flight times and therefore higher productivity

The estimated flight envelope of Condor is compared to that of Cock in figure 26. This figure shows the speed and altitude limits of the two aircraft as a function of gross weight

Cargo Capacity. Figure 27 shows three prospective cargo loadings. The great size of Condor means that intact military units up to company size can be carried in a single aircraft. As shown in figure 28, four Condors would be able to carry a full airborne battalion, with all 354 troops riding on the upper decks and with the vehicles being carried on the cargo decks.[9]

Condor may be able to carry an SS-20 transporter-erector-launcher (TEL) carrying the missile. The limiting factor in this case is the height of the TEL plus missile. We cannot with certainty determine if the TEL plus missile can be carried, however, because of the uncertainty in this height estimate. Even if the height of the TEL plus missile is low enough to be loaded on Condor, some special loading equipment (at least a very long ramp extension) will be required because of the combination of the great length and height of the TEL plus missile. The AN-22 Cock also may be able to carry an SS-20 TEL with missile, although special loading equipment again would be required. The SS-20 TEL plus missile weighs roughly 80 metric tons, split more or less evenly between the TEL and the missile.

Condor probably will be able to carry an SS-20 missile and its TEL if the missile is loaded separately on its transport dolly. Some special preparations or equipment, such as a ramp extension, may be required to load the missile dolly. If the SS-20 missile canister could be loaded on a special (purpose-built) narrow-track air transport cradle, two missile canisters probably could be loaded in addition to the TEL. In this case, special loading equipment almost certainly would be required. If the TEL and missile are separate, a Cock could carry either the TEL or the missile, but not both, because of space limitations.

Roles and Deployment

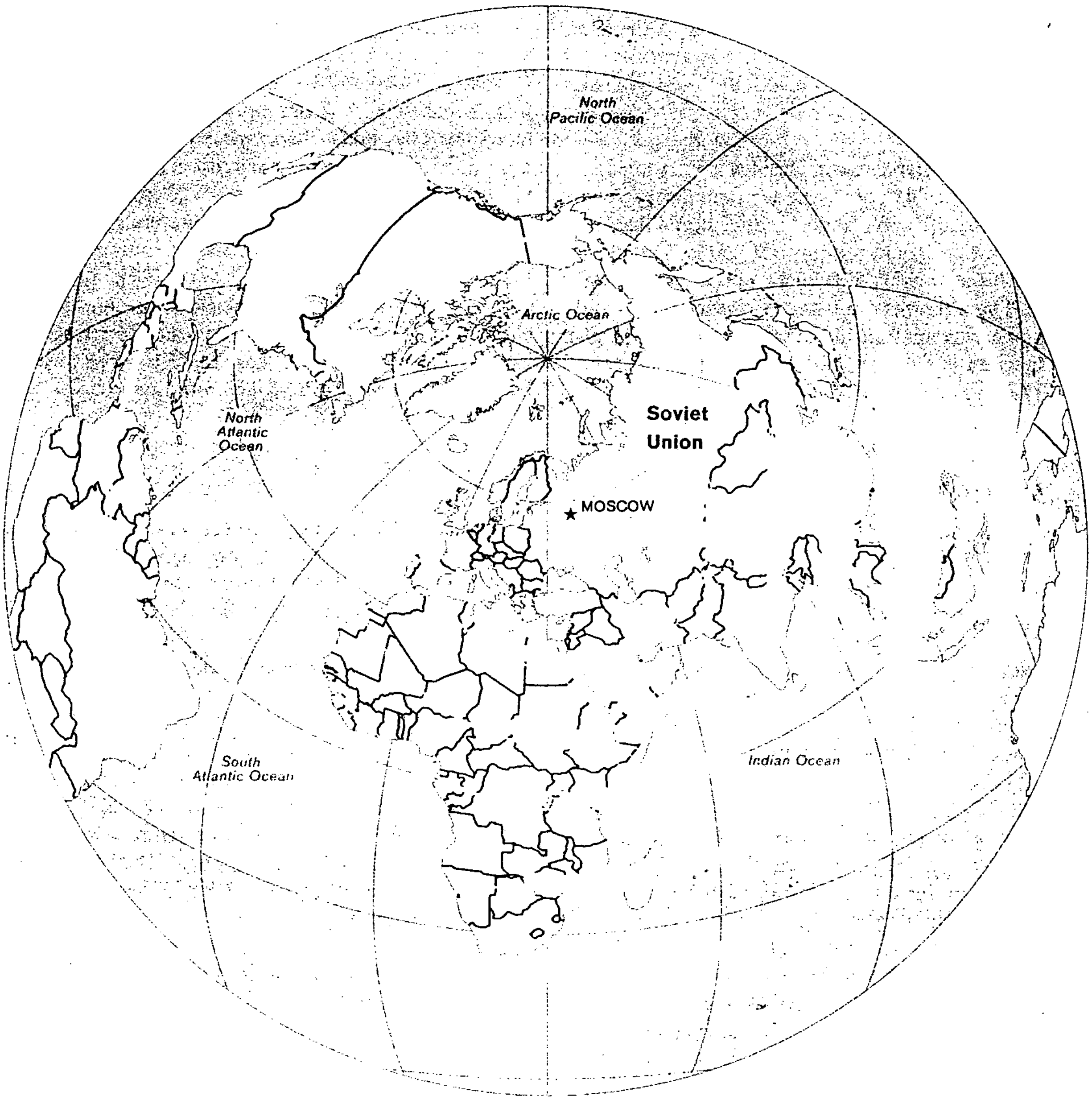
Condor probably will begin entering service in 1987 or 1988. It is expected eventually to form the backbone of VTA's heavy airlift fleet. We do not expect Cock to be phased out immediately as Condor enters service. Instead, we believe Condor will at first supplement and later completely replace Cock in the heavy airlift role.

Besides its obvious role as a heavy military transport, Condor probably will be used also in a civil role to support activities in remote areas of the USSR. For example, the Soviets have mentioned a role in support of oilfield operations in remote areas. They claim that Condor can carry 80 percent of Soviet heavy petroleum equipment.

Our estimates of Soviet military requirements and production capability suggest the Soviets will have about 70 Condors deployed by 1995. Total production of Condor may exceed 100 aircraft before production ends. The Soviets' current heavy airlift fleet consists of 57 Cocks permanently based at three airfields near Moscow. Condor probably will be deployed to the same airfields that support Cock units

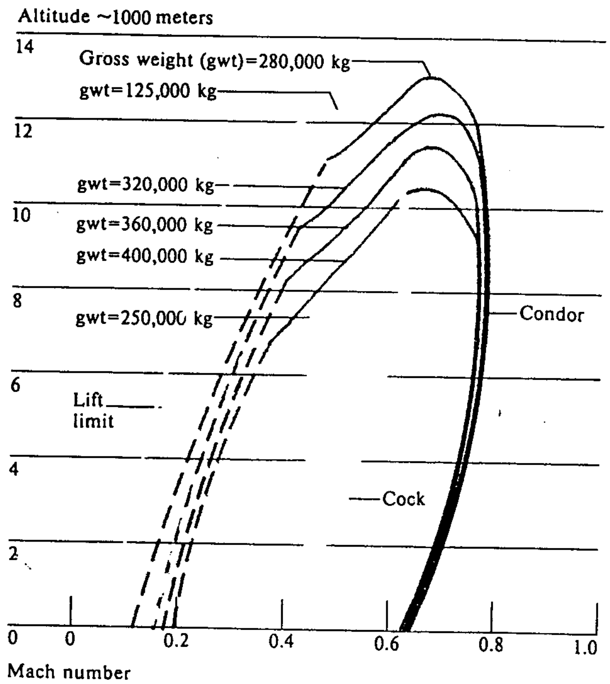
[9] A Soviet airborne battalion consists of 354 officers and men and roughly 300 metric tons of vehicles—31 BMD infantry fighting vehicles, 10 trucks, seven single-axle trailers, and two light trucks.

Figure 25
Condor Payload Coverage Capabilities



Boundary representation is not necessarily authoritative.

Figure 26
Flight Envelopes for Condor and Cock



The increased capability offered by 70 or more Condors compared to 57 Cocks reflects our belief that Soviet heavy airlift requirements have increased. This requirement has built up over the 20-year period between the first Cock deployments in 1967 and the first Condor deployments in 1987 or 1988. A major factor in the increased requirement has been the increase in Soviet overseas commitments

In terms of fleet single-sortie lift capability, 70 Condor aircraft have about 2.1 to 2.3 times the payload weight capacity of 57 Cock aircraft for stage lengths of up to about 8,000 km. Because Cock's payload capability falls off more sharply and at a lower range than does Condor's, a fleet of 70 Condors is vastly superior to a fleet of 57 Cocks if the stage lengths exceed about 9,000 kilometers

Figure 27
Sample Payloads for Condor

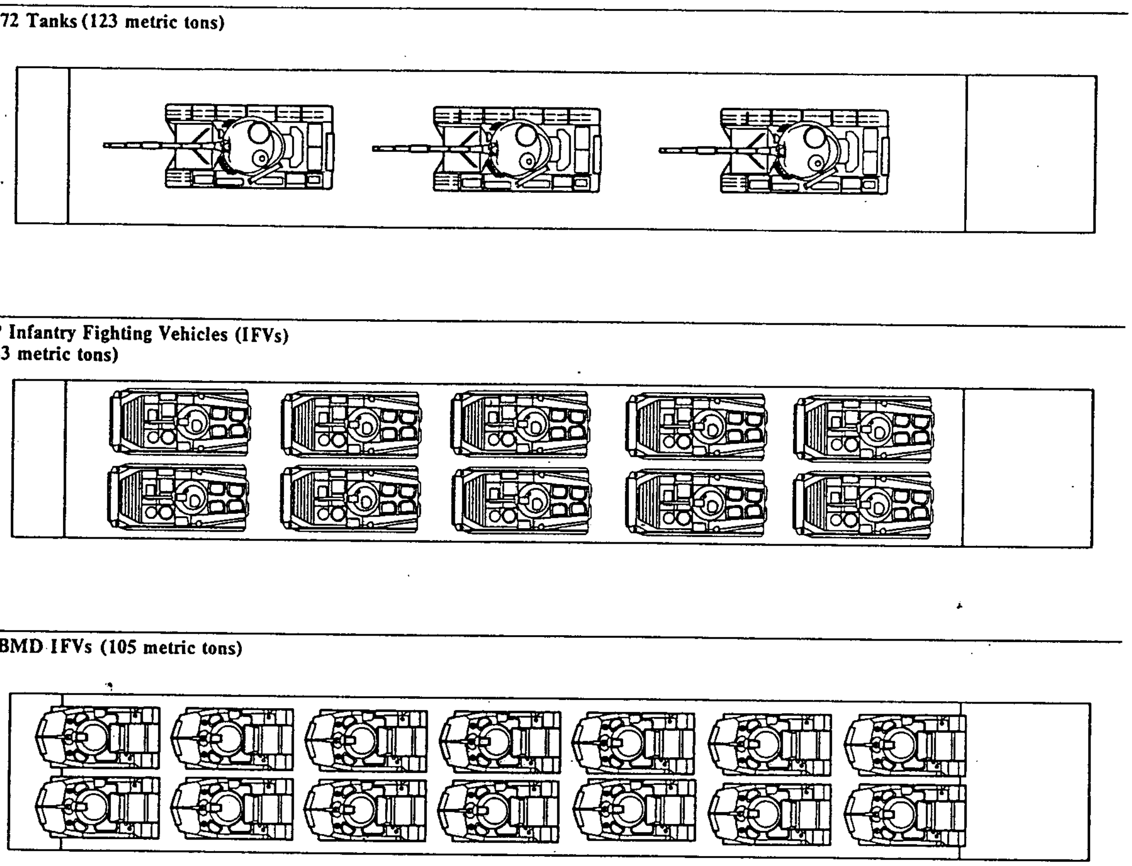
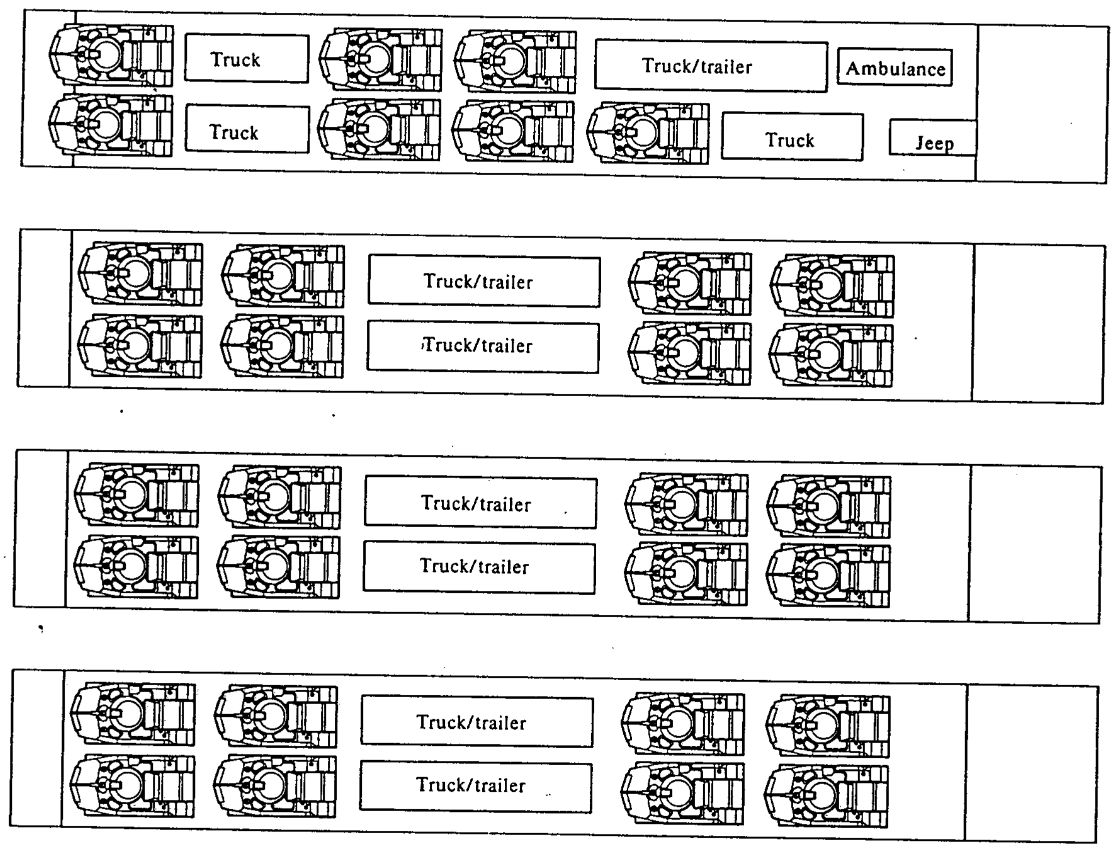


Figure 28
Airborne Battalion and Equipment Carried on Four Condors

70 to 75 metric tons per aircraft



Note: Includes 354 troops riding on upper decks.