

Designing for Future Heavy Lift: The Joint Transport Rotorcraft

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Abstract

During the first decade of the new millennia, U.S. industry and various government agencies propose to embark upon a series of revolutionary technology thrusts whose purpose is to enable rotorcraft to counter new military threats with greater speed, range, and payload using more affordable, long-range aircraft. One such development is the future heavy-lift replacement aircraft, frequently referred to as the “Joint Transport Rotorcraft” and sometimes as the “Future Transport Rotorcraft” (hereinafter, the “JTR.”)

The US Army has a requirement to transport troops, equipment, and supplies throughout the battlespace in support of combat, stability and sustainment operations. The CH-47 Chinook has been the Army’s primary cargo helicopter used to perform these missions since it was first fielded in 1962. The US Air Force, Marine Corps, Navy and Special Operations Force (SOF) use the CH-47, CH-46 and CH-53 for similar missions.

While the Army initiated the CH-47F Improved Cargo Helicopter (ICH) program to prolong the life of the CH-47 platforms, by the time the JTR enters service even these helicopters will be nearing more than 60 years of age. Based on the cargo helicopter fleet’s increasing age, obsolescent technologies, and limited capability to perform on future battlefields, a replacement system will be needed.

To meet this requirement, US industry plans to invest significant resources in internal research and development, matched in some cases by NASA and the US Department of Defense, to perfect new designs, materials, structures, and advanced diagnostics, and develop new communications, navigation and surveillance capabilities.

This presentation describes the background and issues relating to the JTR development process. It also comments on government and industry technology programs intended to deliver on “stretch goals.”

1. JTR Concept Overview

The Joint Transport Rotorcraft (JTR) is envisioned by the US Department of Defense to be the replacement system for the US Army’s CH/MH 47 Chinook and potentially the Navy/Marine Corps’ CH-53 Super Stallion helicopters, as well as the Navy’s Carrier Onboard Delivery (COD) aircraft. It is also expected to provide a complimentary operational capability to the US Navy and Marine Corps’ V-22 tiltrotor aircraft. The JTR should also meet emerging needs of the DoD’s logistics mobility requirements, which include intra-theater projection of the Army’s postulated medium divisions and objective force, USMC Expeditionary forces and Operational Maneuver from the Sea (OMFTS).

Logistics mobility is a key aspect of the US Army’s Chief of Staff “vision” and

includes the capability to provide tactical, intra-theater, and potentially inter-theater transport of the Army's Future Combat Systems (FCS) and the Marine's Amphibious Assault Vehicles and Light Attack Vehicles.

As a potential joint program, JTR is intended to provide a significant increase in mission capabilities over and above current DoD vertical take-off and landing (VTOL) systems combined with a significant improvement in affordability. Reduction in cost of ownership, as compared to existing systems, might be achieved partially through commonality in joint training, supportability and integrated logistics support requirements. Operational and support (O&S) costs might be reduced by "built in" improvements in reliability, availability and maintainability of the JTR systems and through the use of integrated diagnostics and "intelligent" prognostic subsystems. The DoD believes that the potential also exists for international and commercial derivatives to be built which could effectively reduce both development and production costs.

As currently planned, the JTR program strategy calls for first units to be fully equipped with JTR in 2018, with Engineering and Manufacturing Development (EMD) beginning in 2010. A Program Definition and Risk Reduction phase would occur from 2006 to 2009, preceded by a number of major system 6.3 technology demonstrations from FY '01 to FY '05.

2. The 1976 Interservice Helicopter Commonality Study

What are the benefits offered by a "joint" or "commonality" approach to helicopter procurement? The *Interservice Helicopter Commonality Study*, performed in 1976 by the office of the Director of Defense Research and Engineering, represents the seminal report on the benefits, and challenges, of

interservice cooperation in the development and procurement of helicopter systems.

In response to concerns expressed by the United States Congress and Government Accounting Office (GAO) in 1974, the Director requested a joint steering committee chaired by the US Army to investigate the trend toward the proliferation of types of helicopters and the high costs associated with their development and operation.

The purpose of the study was to determine the feasibility of helicopter commonality as a means to reduce the basic types of helicopters in development and future helicopters in the DOD inventory (then approximately 10,000). The group defined commonality as "the use of a single helicopter design or variants thereof to satisfy more than one operational requirement within a capability group."⁰

The study yielded the following conclusions:

- Interservice helicopter commonality is feasible in terms of the use of a single helicopter design or variants thereof to satisfy more than one service's missions within a capability group.
- It is not necessary to reduce the various service's requirements to a standard basis, e.g. a standard hover requirement, in order to implement helicopter commonality. The baseline helicopter provides a common reference for comparison of diverse service mission requirements without the need to modify any of these requirements. Thus, service missions having difference payloads, hover requirements, and mission profiles can be compared without modifying these requirements.
- It is possible for similarly named service missions, e.g., Army troop transport, Marine troop transport, to

have such diverse requirements that they cannot be satisfied by the same helicopter type.

- A commonality helicopter will have shortfalls and excesses of capability relative to the service's mission requirements. The attempt to design a single helicopter to perform all the missions within a given capability group results in a helicopter that performs some of the missions exactly; for some missions does not accommodate all of the mission requirements; and performs some missions beyond the requirements.
- The concept of variants to the baseline helicopter is essential to minimizing the number of helicopter types. Variants, which are derivatives of the baseline helicopter, employ changes to the baseline helicopter airframe or dynamic systems to satisfy a particular operational requirement.
- Joint participation is required from the outset for a successful commonality program.
- The cost impact of commonality depends on the details of each group of requirements and must be separately evaluated for each case. Commonality can produce significant RDT&E (research, development, technology and engineering) cost savings. The impact of commonality on procurement cost is smaller and, in some circumstances, can be a cost penalty. The complete cost impact of commonality can only be determined by a full cost and operational effectiveness analysis for each case.

The final conclusion reached by the Study Group was that a DOD family of helicopters, e.g., commonality, was feasible.

Unfortunately, the Study Group disbanded in 1976 and failed to perform

the second (cost analysis) and third (implementation) parts of the Study. The effort to harmonize Army, Navy, Marine Corps and Air Force requirements was terminated. Nevertheless, the services – driven by budget constraints - did accept in practice the notion that a baseline helicopter, with several variants could perform a wide range of service missions. For example, the UH-60 Black Hawk in various configurations currently performs different missions for the Army, Navy, Air Force and Coast Guard.

3. New Warfighting Operational Concepts Define JTR Capabilities.

The US Army's Army After Next (AAN) research and Force XXI experimentation indicate that the twentieth century patterns of combat will not apply to 2020 and beyond warfare. While cargo and troop transport missions will be a continuing requirement, future aircraft must be compliant with AAN thinking and Combined Arms Support Commands's (CASCOM's) Precision Logistics Concept. For example, the extended battlefield as well as greater operational tempos mean that future aircraft must possess significant warfighting performance advancements in range, speed, payload, survivability, supportability, and mobility. Future cargo helicopters will be required to fly more tons of cargo each day, faster, over greater distances, and with greater scheduled availability rates.

The Army's Force XXI requirements dictate the need to "project the force, protect the force, gain information dominance, shape the battlespace, conduct decisive operations, and sustain the force." Accordingly, air platforms that possess rapid or self-deployment capabilities will directly advance the force projection objective. Self-deployment platforms will reduce the burden on strategically deploying platforms, expand the number of approaches into the theater, and provide an enormous degree of operational flexibility, thus enabling forces to reach

anywhere in the battlespace in a matter of days.

Aviation forces can be used to accomplish rapid force resupply. The key is to deliver sufficient critical supplies to sustain the operation, which equates to a force protector. Aviation plays a role in sustainment. Sustainment is aided by aviation's ability to rapidly self-deploy, conduct intra-theater air movement of critical supplies, and provide aerial resupply to forward-deployed troops, to move personnel and equipment over a wider area, thereby ensuring asset availability and shortened down-time on equipment. Aviation will also continue to play a significant role in future efforts in peace enforcement and peacekeeping by delivering relief supplies when surface transportation is insufficient or routes become impassible.

Future operational capabilities (often referred to as FOCs) or future enhancements to aviation needed to bring the Army to the Army XXI level are described in the US Army TRADOC Pamphlet 525-80, *Army Aviation Warfighting Concept of Operation*. These include the following:

- To self-deploy worldwide and be rapidly operational with minimal support upon arrival.
- To operate in and from unimproved areas.
- To conduct shipboard operations.
- To operate in worldwide conditions of hot, cold, wet and dry, and adverse conditions, e.g., blowing sand, dust, salt spray, etc., with minimal aircraft damage or degradation.
- To meet mission requirements through enhanced aircraft performance, e.g., range, speed, agility, maneuverability, lift, specific fuel consumption, etc., at terrain heights and higher.

- To transport combat, combat support, and combat service support personnel and their associated equipment and supplies in an effective and timely manner to maintain the operational tempo.
- To transport current and future light infantry fighting vehicles, air defense systems, artillery systems, and engineer's equipment in an effective and timely manner.
- To transport cargo internally with rapid loading and unloading with minimum manpower requirements.
- To transport cargo externally with automatic hookup and sling load stabilization.

Most, if not all, of these Force XXI Army capabilities will in all likelihood become JTR requirements.

4. The Pentagon's JART Study (1999)

Following the conclusion of the Quadrennial Defense Review, the Pentagon's Joint Staff (J-8) in 1998 determined to perform a new study on the possibility of harmonizing requirements which soon became known as the Joint Advanced Rotorcraft Technology Office (JART) Study. Its purpose was to assess the benefits of establishing a joint office for future rotorcraft requirements and advanced technology development.

The working group's findings were adopted by unanimous vote:

- The JART Office concept is feasible, supportable and desirable.
- The working group should be converted into an Integrated Concept Team (ICT) with a leader from the J-8 or with a rotating service lead.
- The first formal ICT should be convened in FY99.

- The JART Office should be started up in FY03 or soon thereafter.
- The Pentagon should immediately perform an Overarching Rotorcraft Commonality Assessment Study (ORCA) whose purpose would be to assess commonality in future DOD rotorcraft requirements and technology developments and present insights for potential investment strategies.

Approved by the JROC in November 1998, the Pentagon launched the ORCA Study and immediately began assessing future operational capabilities and deficiencies for “generation-after-next” rotorcraft. Initially the members began reviewing relevant, available technologies, developing insights for investment strategies, and pursuing a comprehensive “way ahead” vision for commonality opportunities that included the needs of DOD, Department of Transportation (US Coast Guard), NASA, FAA and private industry

In addition to the creation of the JART Office, the ORCA study considered a number of performance requirements which would best address the heavy lift replacement needs of all of the service branches.

5. Potential Heavy Lift/JTR Requirements

The ORCA Study compared key performance parameters for heavy lift, including payload, combat radius, speed, deployability, shipboard capability, and VTOL capability based on the needs of each service branch. What the members found was that speed was the only barrier to a JTR common approach.

The Army seeks a VTOL aircraft with a payload greater than that of the CH-47D (10 to 13 tons); a combat radius greater than the CH-47D (500 to 1,000 km); a speed of 175 to 250 kts; self deployability (2,100 nm) with in-flight

refueling; and shipboard compatibility (transient).

The Navy and Marine Corps desire a VTOL aircraft with payload greater than the CH-53E (17.5 tons); a combat radius great than the CH-53E (480 to 800 km); a speed of 250 to 300 kts; self-deployability with in-flight refueling; and shipboard capatibility (sustained).

The Air Force, with an air rescue requirement, seeks a VTOL aircraft with a four ton payload; 500 km combat radius; more than 170 kts speed; self-deployability with in-flight refueling; and shipboard qualification.

The Special Operations Command (SOCOM) seeks a VTOL aircraft with a 12.5 ton payload; an 800 km combat radius; speed of 180 to 300 kts; with shipboard capatibility (marinized). The ORCA study was silent as to deployability.

A comparison of the differing service requirements yields a requirements band for the JTR as follows:

JTR Requirements	
Speed	175 – 300 kts
Payload	18 – 26 tons
Range	300 – 1000 km (combat radius)
Op Capability	Intra-theater, unprepared surface
Self-deployment	2,100 nm

Projected missions for the JTR include port alleviation, the ability to carry a 20 ton Future Combat Vehicle (FCV), air assault, forward logistics, and ship-to-shore resupply.

During 1999, the Army convened a JTR Independent Review Team led by George T. Singley III to assess the

Army's future needs for heavy lift. Among its recommendations to the Commanding General of the Army's TRADOC command were the following:

- Beginning in FY 2000, the Army should award three airframe manufacturers (with engine manufacturer participation) two-year contracts for parametric analysis, advanced concepts, technology assessment, modeling simulation, and IPPD.
- Revise current JTR science and technology efforts (S&T Roadmap) to improve affordability, reduce technical risk and improve technology readiness to achieve a 2018 FUE (first unit equipped).
- Establish a Defense Acquisition special task force.
- Increase DARPA leverage (Joint Logistics ACTD; Advanced Logistics Program; Open-Systems Architecture; Simulation-Based Acquisition; Variable Diameter Tilt-Rotor; Face Gear Transmission)
- Consider JTR S&T cost sharing among NASA, USN/USMC, DARPA, and Army.
- Explore international participation with non-US airframe and engine manufacturers and suppliers.
- Synchronize the JTR and FCV programs to provide Strike Force "breakthrough" capability.
- Ensure JTR requirements incorporate 22.4 ton MILVAN, ISO container and pallet commonality with C-130 and C-130 follow-on.

6. US Army Aviation Modernization Plan; JTR S&T Development

The Army's latest aviation modernization plan issued in March 2000 refers to the JTR as the "Future Transport Rotorcraft,"

reflecting the service's view that JTR is not yet a formal "joint" requirement. The plan, nevertheless, clearly defines the FTR/JTR as the key enabler to meet the transport requirements of the Future Combat System for the future Objective Force beyond 2020: "The FTR will provide an advanced aviation system enabling full spectrum strategic responsiveness through global self-deployment."

In order to achieve a FTR phase-in in the 2020 timeframe, the Army modernization strategy emphasizes the importance of various S&T programs now underway or planned in the near term to achieve performance advancements in range, speed, internal cargo volume, lift, survivability and mobility with reduced acquisition and support costs. Among these are the following.

Joint Turbine Advanced Gas Generator III. This is the final phase of the DOD Integrated High Performance Turbine Engine Technology program which will ultimately lead to a 10,000 shp engine demonstration to support the JTR.

Advanced Rotorcraft Transmission II and the Rotorcraft Drive System for the 21st Century. These efforts will enable new transmissions to handle more horsepower per pound of transmission weight. They will also generate less frictional power loss and heat generation, less noise and vibration, have fewer internal parts, and will extend the time interval between repairs and overhauls.

Variable Geometry Advanced Rotor Technologies; Helicopter Active Control Technologies; Advanced Rotorcraft Aeromechanics Technologies; Variable Geometry Advanced Rotor Demonstration; and Low Cost Active Rotor. These efforts are focused on providing more efficient conversion of horsepower into lift over a wide range of flight conditions, thus enabling the FTR/JTR to lift more and fly

further per unit of fuel consumed. The Low Cost Active Rotor will develop on-blade control technology with the purpose of eliminating mechanical control devices such as the swashplate and pitch change links.

Rotary Wing Structures Technology Demonstration Program; Survivable, Affordable, Repairable Airframe Program. These efforts are intended to develop, integrate, and demonstrate new technologies to provide efficient and affordable large scale composite airframe structures with diagnostic and repair concepts that address tolerance to combat threats, reduce repair time, increase useful life, and reduce airframe weight.

The combined effect of these and similar technology programs are reduction of aircraft size through increased efficiency of engine, rotor, structure and drive systems; reduction of operating and support costs by 50%; reduction of aircraft noise by 75% or more; and reduction of fuel burn and logistics tail by more than 50%.

7. The Future of JTR

Although the Joint Transport Rotorcraft has been endorsed in principle by senior executives in the Department of Defense and general officers of the Pentagon's Joint Staff and the Army and Marine Corps, JTR has failed to generate sufficient interest and support to result in a budget allocation in the near future. As defense expert Robert McDaniel observed in a recent *Vertiflite* article, "with no real pressures to replace Chinooks or Sea Stallions on the horizon, the JTR must perform some other more compelling role if it is to acquire a life."

But what role? McDaniel makes a compelling argument that JTR is an essential component of an effective Global Combat Support System to meet the needs of the Revolution in Military Affairs (RMA) and the Army After Next (AAN). These new concepts place a far

greater premium on mobility than did earlier doctrines based on Cold War scenarios. The ability to transport the standard MILVAN container with a rated gross weight of 22.4 tons and dimensions of 8 x 8 x 20 feet appears highly important in this context, since it is widely used throughout the services for the movement of supplies and equipment. It is, moreover, increasingly being configured as a shelter for communication systems, command shelters, maintenance shops and other functions. In addition, it is a primary enabler of the Army's Global Combat Support System, since it can be transported by container ships and aircraft in current military service such as the C-130, C-141, C-5 and C-17. For these reasons, McDaniel argues persuasively, the Joint Transport Rotorcraft should be sized and configured with the MILVAN container as the critical load.

At this time, all configurations are under consideration by the Army, including helicopters – single main rotor and tandem; tiltrotors, including variable diameter tiltrotors and Bell's proposed Quad-Tiltrotor; and tiltwing aircraft. There are design tradeoffs which must be addressed. Helicopters, with their lower disc loading, offer better hover efficiency, while tiltrotors offer greater speed. McDaniel suggests that tandem rotor designs provide compelling advantages: a smaller rotor diameter, reduced disc loading (10 psf), and the ability to control attitude. He observes that the Boeing BV-360, an experimental helicopter featuring retractable gear and a low drag design, demonstrated a cruise flight potential of greater than 200 knots without the need for horizontal thrust augmentation.

The only helicopter in the world currently capable of lifting a 20 ton fully loaded MILVAN container is the Russian Mi-26. Writing in *Vertiflite*, Dr. Marat N. Tishchenko, the designer of the aircraft, contends that the Mi-26 could be modernized to meet all JTR

requirements with the exception of cruise speed. The principal challenges would be the development of an engine capable of 12,000 shp, main gear box modernization, new main rotor composite blades, retractable landing gear, modernization of the fuselage, and new systems for electronic, hydraulic, electrical and cargo handling.

The debate will continue, but in all likelihood until the Army and the US Marine Corps can agree on a common approach to the Joint Transport Rotorcraft, it is unlikely much progress will be made. The failure of the services to approve the creation of a joint rotorcraft program office to harmonize service requirements is admittedly a setback, but it is not the death knell for a heavy lift replacement. The Army's rotorcraft S&T programs now underway are highly appropriate and well-designed to support JTR goals and objectives. But they will require increased funding and improved focus if the services are to achieve a 2018 to 2020 operational capability.

Several issues are clear. The U.S. Army - the lead service in the U.S. for rotorcraft development - is changing its approach to warfighting doctrine. The chief of staff's vision for the future "Objective Force" is highly dependent on vast improvements in logistics mobility. JTR, with greater speed, range and payload, will play an integral role in facilitating mobility. The sooner the service and DoD can prioritize JTR and synchronize its development with that of the Future Combat Vehicle, the sooner the Army's new vision will be achieved.

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