

COMANCHE TECHNOLOGY STATUS

Dr. William D. Lewis
Aviation Engineering Directorate

James M. Richey
Comanche Program Office

Redstone Arsenal, AL, USA

Abstract

The RAH-66 Comanche program was cancelled in late February 2004; approximately eight months before the first LRIP aircraft would have been integrated. The status of key component and software developments are outlined in the paper. Additionally, the benefits of an integrated platform are stressed. The technology transition plan for these components and capabilities is outlined.

Comanche Technology Status at Time of Termination

Comanche was the most technologically advanced helicopter yet developed by the American helicopter industry. Practically every component was a new, unique, or highly modified design incorporating state-of-the-art technologies. At the time of termination, the first Engineering and Manufacturing Development (EMD) aircraft was in assembly at approximately the midpoint with four other aircraft in the assembly line behind the initial aircraft. The first aft fuselage was to be delivered and attached to the forward fuselage in just a few weeks. In October of 2004, 8 months after termination, aircraft three would have been at control point 20, where final assembly was to begin and all parts and components would have been completed and ready for final assembly. At the time of termination, there were two flying prototype aircraft that were built in the earlier Demonstration/Validation (DEM/VAL) phase of the program. Prototype number one was in storage after completing early envelope expansion and initial development of the air vehicle. Prototype number two was in active flight test developing the mission equipment.

Airframe

Fuselage

Both the forward and aft fuselage were in assembly with the aft only days from completion. The fuselage join would have occurred approximately one month after termination. The fuselage sections were almost entirely composite except for fasteners and fittings. The primary structure was graphite epoxy (IM7/8552). The lower aft fuselage skins under the exhaust ducts utilized a Bismaleide resin system (IM7/F655) to withstand high temperature from the exhaust ducts. This condition only occurred during sideward flight and would have been of limited duration. The decision was made not to restrict the flight envelope from sustained sideward flight, but to increase the operating temperature limits of the skins in this area. In addition to graphite (IM7) both Kevlar and Astroquartz were being used over the non-metallic honeycomb core. The desired characteristics of local areas were the determining factor in which skin material was used. In some areas the honeycomb core was replaced with X-cor™, a type of foam with carbon pins embedded in the z-axis. The X-cor™ provided weight savings while retaining the strength of honeycomb in non load bearing applications. In another new technique, the canopy frames were laid up over foam mandrels and the foam material was removed by bead blasting after curing to reduce weight. We believe this was a significant accomplishment in fabrication techniques for frames and rails.

One of the few large metal components on the aircraft was the one piece titanium rotor hub. The hub had been milled and was awaiting whirl tower testing with the other rotor system components. The main rotor quill shaft was also

manufactured from titanium. In the DEM/VAL program, a number of quill shafts were made of composite, but difficulties were encountered in curing due to the thickness and also in attaching a metal retention flange to the bottom of the shaft.

Main Rotor Blades

The blades had an advanced airfoil with swept anhedral tips and incorporated ballistic protection as well as signature reduction features. The EMD blades had a 16" chord vice a 15" in the DEM/VAL blades. The larger chord provided more space for the spar and a better opportunity to design for ballistic tolerance. The ballistic requirement was met by the 15" chord DEM/VAL blade, so there was high confidence the 16" chord blade would meet the requirement. Assembly was nearing completion for the first blade at the time of termination. The combination of hinge offset 11.3% and highly responsive flight control actuators provided capability for high agility, but also high load generation. All the rotor system components, including hub, flexbeam, and blade, had undergone redesign to accommodate load increases and tuning to match stiffness. Additionally the original snubber dampers had been replaced with through flexbeam dampers to provide significantly greater life.

Flexbeams

In the previous DEM/VAL program when the original flexbeams were fabricated, the yield was quite low due to fiber washout and porosity resulting from pressure molds used in curing. For the EMD the fabrication methodology was changed to autoclave cure which provided much better yields.

Main Rotor Gearbox

The main rotor gearbox was rated at 2400 horsepower (HP) and designed as a "split torque" design. The split torque gearbox provided a low profile that allowed a reduction in the overall height of the aircraft. The initial EMD gearbox housing was milled from a magnesium casting, WE 43. Low yield rates were experienced with this alloy due to its tendency to segregate in areas of rapid transition in thickness. The gearbox

was in component level testing at termination. Later in the program there was a plan to convert the housing to a resin transfer mold (RTM) composite housing. This effort had not been started at time of termination. A unique feature of the Comanche main gearbox design was the use of spring clutches rather than the more common sprag clutch. The spring clutches had been problematic, and the current design is the third iteration of the basic concept. During flight testing the spring clutch was experiencing excess wear due to the tight fit of the spring clutch and the misalignment between the input bevel pinion and the arbor shaft. A redesign effort was undertaken taken to reverse the spiral bevel angle on the bevel pinion to reduce loads that caused misalignment and to loosen the fit between the inside diameter of the spring clutch and outside diameter of the arbor shaft. The previous designs allowed excessive deflection of the arbor shafts under load. Qualification testing was underway at the time of termination.

Fantail System

The Comanche yaw control and maneuver requirements were substantially greater than typical rotorcraft. To accomplish these required high levels of power to be delivered by the fantail gearbox and drive system. The 930 HP rating of the fantail gearbox required a relatively robust design. During flight testing with the prototype aircraft, there had been torque spikes encountered with the fan system, and power had exceeded 1100 HP for very brief periods of time. This phenomenon had occurred in certain quartering tailwind conditions and is thought to be an adverse reaction to airflow over the duct lip and the fantail blades. The fantail systems were designed to accommodate the power excursions and meet maneuver requirements.

Delivering power to the fantail was accomplished by composite driveshaft. The challenges in designing the composite shafts were in meeting ballistic requirements and, for some sections of the shaft, providing the ability to operate in a high temperature environment. The quill shaft was fabricated from fiber-placed PEEK resin

with IM-7 graphite. In the compartments where high temperatures (>600°F) were a concern, the material selected for use was a polyimide, AVIMID-R. The material, which cures at 640°F, proved to be difficult to use in this application. There were a number of cases of porosity and delaminations due to the thickness of the laminates and outgassing that occurs with polyimides. Six good shafts were fabricated, which was enough to begin testing, but the testing had not been completed at the time of termination. A plan was in place to redesign the shafts again later in the program to increase thickness to ensure they would meet ballistics requirements.

Engines

T800-LHT-802 Engines

The T800-LHT-802 engine provides 1680 shaft horsepower (SHP) maximum power at sea level standard conditions (1231SHP@4kft/95°F). Weight is 340 pounds providing a 5 to 1 power to weight ratio. Current 700 series engines (Blackhawk, Apache) have a 4 to 1 power to weight ratio. With a 6000 hour design life, the T 802 also provides very economical operating and support costs. The engine was scheduled to be fully qualified before the end of this year.

Subsystems Power Unit

The third engine on the aircraft which operated full time was the subsystems power unit (SPU), a Williams WTS 124 turbine. This 170 HP auxiliary power unit provided power for the third electrical and hydraulic systems as well as bleed air to power the environmental control system, and it started the two main engines. This is the same SPU that was used in the prototype aircraft, modified with a new fuel delivery system. The modified SPU was beginning its 150 hour test at time of termination.

Environmental Control System

The Environmental Control System (ECS) provided cooling air to the crew and avionics while filtering chemical contaminants from the air. The ECS was

possibly the most complex and sophisticated cooling system developed for rotorcraft. The basic system was an air cycle machine powered by bleed air from the SPU. The critical components in the system were the High Efficiency Particulate Air (HEPA) filter to remove liquid moisture and the Pressure Swing Adsorber (PSA) to remove water vapor. The primary role of these filters was to remove moisture from the air before it entered the air cycle machine, which would output ice if the air contained moisture. The secondary role of the filters was to remove potential chemical or biological contaminants. The PSA was a dual bed, self-purging, molecular sieve filter bed. By varying the composition of the filter materials, it is possible to remove a wide variety of chemical agents. Additional protection from potential NBC contaminants was provided to the crew from a positive cockpit overpressure supplied by the ECS. The overpressure was approximately .5 pounds per square inch and would serve to prevent airborne contaminants from entering the cockpit if there was ballistic damage to the crewstation. The ECSs in the two prototype aircraft were functionally similar to the EMD design; however, the EMD design contained a number of changes and provided for greater cooling capacity. Two EMD representative PSAs were undergoing testing at the time of termination. Later testing with simulated agents was planned to verify their performance in a chemical environment.

Engine Inlets

The original prototype aircraft engine inlets were conventional forward facing inlets. These were not designed to be compatible with the aircraft radar signature requirement. The initial EMD design was forward facing and treated; however, achieving the signature allocation proved to be challenging. As a result, the design was changed to a side facing inlet using open cell honeycomb for the inlet screen. To address potential icing concerns, the design included bypass doors that opened into the transmission compartment; these would automatically open should the honeycomb inlet be blocked due to icing condition or other debris that could potentially block the inlet. The inlet

had successfully completed icing testing. The altered design had a slight impact on max speed, but little impact on hover or vertical climb performance.


Exhaust Ducts

The Comanche exhaust ducts were also a highly advanced design and key to the reduced infrared signature of the aircraft. The ducts attached to the engines inside the engine compartments and remained internal to the aircraft skin along the aft fuselage. The actual duct opening was a long narrow slot that directed the exhaust gasses down and away from the airframe. The long, thin-walled ducts were fabricated from welded titanium using a plastiforming technique. The titanium was operating near its material limits and the program planned to convert the material to Gamma Ti later in the development schedule. Recently, the availability of a Gamma Ti source became an issue, and it is uncertain if the change could have been made. In addition to the higher material temperature limits Gamma Ti would have provided, its substitution would also have saved approximately 30 pounds of weight.

Electrical System

The electrical system was a 270 volt direct current (DC) system that received primary power from two 30 kilowatt (kW) main generators, which were driven by the main transmission, and the third/backup system, which was driven by another 30 kW generator powered by the SPU. The system had proven to be remarkably trouble-free in the prototype aircraft and had a very low noise floor. All breakers/contactors were software controlled through the cockpit displays. Additional redundancy to operate the flight control computers in the event of a total electrical failure in the primary system was available from two hydraulic permanent magnet generators (HPMG's), which were also driven by the main rotor gearbox. The sole purpose of the devices was to power the digital electronic flight control system in the event of a total electrical system failure.

Flight Control System

The Comanche digital fly-by-wire flight control system (FCS) is the most advanced rotorcraft flight control system that has been developed. Several of the features greatly improved handling qualities and reduce pilot workload. Additionally, the digital fly-by-wire system was more reliable and weighed significantly less than a redundant mechanical flight control system. The Comanche FCS provided two highly augmented modes: rate command/attitude hold, which provided very responsive maneuver capability for day visual conditions, and attitude command/velocity hold, with more benign response for night and degraded visual conditions. Additionally, the system incorporated a number of automated features which includes a flight director and a fully coupled auto-pilot with advanced functions, including auto hover, bob-up, and return to mask. Functions that were to be added in later stages of the program included envelope cueing and integrated fire and flight control. Use of a triplex (triple redundant) electronic architecture with cables in lieu of mechanical linkages provided greater flexibility in routing the wiring and reduced the probability of ballistic damage from threat weapons. The navigation function was integral to the flight control system and relied on three LN 251 (compact/lightweight fiber optic gyros) inertial/Global Positioning System navigators to develop the navigation solution. Also within the flight control system was the rotating air data system. This system obtained air data from blade mounted scoops, while the data processing was contained in a card in the flight control computers. The basic architecture was proven in over 500 hours of flight test on the two prototype aircraft, but the hardware was completely redesigned for the EMD aircraft. The EMD design incorporated new Power  based flight control computers, improved actuators for better overall performance, and reduced susceptibility to ballistic weapons.

Mission Equipment

Sensors

The Electro-Optical Targeting and Designation System (EOTADS) which contained a 2nd generation Forward Looking Infrared (FLIR), television (TV) and Laser RF/D was perhaps the most advanced electro-optical targeting system yet developed for a tactical aircraft. The EOTADS provided the capability for rapid, wide area target searches in an automated mode in which the system would quickly detect and classify potential targets. These targets were presented to the crew as cropped images of the potential target with an automated assignment of target classification according to a crew selected prioritization. This allowed the crew to quickly confirm the classifications and select a course of action to pursue the target or assign it to another weapon system. Several additional modes of operation were available from the system. One was an automated search and storage of the search area which could be replayed to the crew from a masked position, allowing the crew either to confirm the targets and develop an attack plan or to pass the targeting information to other systems. The use of automated detection/classification algorithms to find targets was thought to be essential with a 2nd generation FLIR targeting system. Studies have shown that manual review of target scenes requires considerably more time with a 2nd generation FLIR sensor due to the increase in scene detail and content inherent in 2nd generation FLIR imagery.

The 2nd generation FLIR detector used in the Comanche electro-optical systems was a 480x4 scanned focal plane array operating in the 8-12 micron band, which the Comanche program has always believed provided the best worldwide environmental performance capability. Large format staring focal plane arrays are becoming available, but most of these operate in the 3-5 micron band. It was recognized that the 3-5 micron systems do provide greater focal lengths and support longer range detection and recognition when operated in the manual targeting mode, but

the 8-12 micron band is more compatible with automated targeting. Little work has been done in adapting staring focal plane arrays for rapid scanning of target areas to support automatic target searches. Comanche was planning to incorporate the longer range capability of the 3-5 micron system through a future upgrade to the TV side of the EOTADS. The plan was to replace the day TV with a dual band, visual and 3-5 micron, sensor that could utilize the smaller field-of-view and higher magnification capability of the TV optics.

The first shipset of hardware was completed and undergoing integration testing at the time of cancellation. A number of integration issues had been identified and work-around solutions were being implemented on a regular basis. The most disappointing feature evaluated to date had been the target tracking function which was providing erratic performance. Improvements to target tracking were being worked at the time of termination, but a final solution had not been identified. The second unit was scheduled to fly on prototype number two at the end of April 2004.

The laser rangefinder designator in the targeting system was a solid state diode pumped dual frequency laser in a very compact package. The 1.54 micrometer "eye safe" mode was to be used for range finding and training, and the 1.06 mode would be used primarily for designation with the Hellfire missiles. The laser development had been completed for some time, but it had not been tested as a part of the overall targeting system.

Night Pilotage System

The system included both a wide field-of-view (FOV) FLIR and Image Intensified TV sensors and was located in a highly integrated, but separate, turret on top of the EOTADS turret. The system provided a 35 x 52 degree FOV to the crew for display on a binocular helmet display that could display the full FOV. The FLIR sensor had been completed and flown for a short time on prototype number two in 2003. It had been removed for upgrades and modifications and was scheduled to return to

flight at the end of April 2004 when the full capabilities of the electro-optical systems were to be installed on prototype two and tested in flight. The Image Intensified TV sensor was still in development and was not scheduled to be integrated until later in the program. The pilotage system operated at a 60 Hertz (Hz) rate. Likewise, the image on the helmet display updated at a 60 Hz rate. The helmet display provided 960 vertical resolution lines for a very high resolution image. To support the 960 line display, the image frame was essentially two interlaced fields from the sensor.

The helmet display system represented a significant development effort and was the result of many years of continuing development. The image sources were one inch flat panel liquid crystal displays (LCDs). In earlier versions of the helmet display, miniature cathode ray tubes (CRTs) were used as image sources. Replacing the CRTs with LCDs provided a significant weight reduction for the overall helmet system and the head borne weight. The other significant advantage of the LCDs was the low power required for their operation. In contrast, CRTs required a very high voltage (13 kilovolts) to operate and brought with them the attendant weight and safety impacts of high voltage cables and connectors. The change to the LCD image sources finally allowed the helmet system to be constructed lighter than its specification weight of 1.8 kilograms, which for many years had seemed to be an unachievable weight for a binocular helmet display system. A key component of the helmet display system was the helmet/head tracker that must be used to specially locate the projected image. The tracker was a magnetic system that had proven to be difficult to map to the cockpit and was thought to be the source for some of the latency in the pilotage system. Although a better technological approach was needed, none had been identified to date. Initial testing of the full pilotage system with the helmet display identified a number of integration issues that were still being worked at time of termination.

Aircraft Survivability Equipment

The Comanche Aircraft Survivability Equipment (ASE) consisted of all passive receivers that could detect radar and laser threat systems and provide identification and relative bearing to the threat emitter. The radar warning receiver (RWR) function also provided very high accuracy direction finding accuracy as well as identification of the specific threat. The laser warning receiver provided direction finding and threat identification, but its direction finding capability provided less accuracy than the RWR. These systems were to be fully integrated into the sensor suite and would provide their information directly to the mission computer for display in the cockpit on the multifunction tactical situation display. Both of these sensors were in development at time of termination. A third sensor within the ASE suite was a point chemical detector that detected the presence of chemical agents and displayed this information to the crew through the cockpit displays.

Communications System

The communications system was a lightweight, software programmable radio that was modular and scaleable with an open architecture that would be Software Communications Architecture (SCA) compliant. The system was designed to meet the most robust voice and digital data aviation requirements to date. The COMSEC/TRANSEC capability was hosted on digital cryptography processor modules within the modular racks. The system also incorporated internal power amplifiers and antenna interface units within the two separate enclosures that contained the modules. The system provided the smallest and lightest tactical communications suite used on any aircraft platform. The communications system was a derivative of the F-22 fighter communications system and shared many hardware and software items. The F-35 Joint Strike Fighter program is using the same basic architecture and later versions of hardware modules. The Joint Strike Fighter's UHF/VHF receiver/transmitter modules are the same, merely programmed differently depending on the links required for the mission. Five full shipsets of hardware were in integration

testing, and the first delivery to the aircraft prime contractor was scheduled for delivery in May of this year, when aircraft system level integration would begin. Functional capability was being added through software releases that were to occur over the next couple of years. RF hardware "shrinkage" was planned for September of 2006, prior to delivery of the first block of aircraft. The Comanche communications system was functionally equivalent to the Joint Tactical Radios System (JTRS) now in development and weighed significantly less. It was compatible with and expected to utilize the waveforms developed by the JTRS program.

Antennas

A major success within the program was the development of conformal communications antennas that not only provided adequate performance without compromising the signature control aspects of the aircraft, but were still able to be integrated into a very limited amount of space. The primary locations for the communications antennas were the horizontal stabilizer and the vertical "end plates" which attached to the stabilizer. The UHF, VHF AM/FM, IFF, Link 16 and SATCOM antennas were located in these components. In a recent test, the SATCOM antenna, which consisted of separate 10 inch transmit and receive elements, performed as well as the standard external SATCOM antenna. Another unique antenna was the secondary UHF/VHF antenna that consisted of a radiating element attached to the inside skin of the gun shroud. None of these antennas used active tuning. Full scale pole model testing had been completed on each design, but aircraft testing was not scheduled until flight test began on the EMD aircraft.

Weapons

It was planned that Comanche would fire the RF and SAL HELLFIRE missiles as well as the family of 2.75" HYDRA 70 rockets, but these capabilities were still in the early stages of development at termination. The lightweight, three barrel 20 millimeter (XM301) cannon was further developed, weighing 80 pounds less than

the M-197 used on many fielded helicopters and having the capability of firing both percussion and electrically primed rounds. The gun had completed 10,000 round firing tests but was not fully qualified. A composite single trunnion mount for the turret was still in fabrication. A new aluminum cased, percussion primed, 20 millimeter round was also in qualification testing. Individually, the rounds are approximately 0.16 pounds lighter than the standard, brass cased round. The total weight savings of the aluminum rounds was 80 pounds for the full 500 round capacity. The percussion primer was being used to facilitate shipboard operations. The addition of a four shot rocket pod was also in development. The pod attached directly to a HELLFIRE rail and could fire the family of 2.75 inch rockets. Integration of the Joint Common Missile and Advanced Precision Kill Weapon System (laser guided rocket) was planned later in the program.

Crewstation

The crewstation design began very early in the program and evolved through many years of analysis, design, and motion base simulation. A number of analytical and simulation activities had been used to develop the basic layout and to optimize the controls and display of information to the crew. Although designed as a tandem crewstation, the front panel area was limited by the fuselage mold line, which limited the available display space. The primary panel displays were two 10 inch diagonal, flat panel, liquid crystal, color multi-function displays. One of these was the tactical situation display, and the other was used for target acquisition system imagery. The primary flight display was the helmet mounted display, where all required flight information was displayed along with imagery from the night pilotage system. There were also two additional multi-purpose displays (MPDs) on the lower sides of the panel for displaying aircraft systems status and information. The right MPD also served as the back-up display should a total mission equipment failure occur; in the event of such a failure, that MPD could be driven by the flight control system. The flight controls included a multi-axis right side arm controller for pitch, roll and yaw. Foot

pedals controlled only brakes and had no yaw authority. A left side power controller was used for most power changes, although the side arm controller had limited power control authority for some flight conditions. The use of the side arm controller as opposed to traditional helicopter controls provided the crew an almost unobstructed view of the panel displays.

Much effort was expended in matching the displays to the sensor to ensure the sensor information was not compromised by the display. All targeting performance requirements were based on the image presented on the crewstation displays. As with most aircraft programs, many issues were being worked related to the display of symbology on both the helmet display and the panel displays. The Comanche program had pioneered "contact analog" symbology, which allowed symbology to be stabilized relative to the outside view versus a more conventional stabilization based on the display surface. This issue was to be resolved in flight test and could have resulted in a major change in how symbology was displayed.

The crewstation design and controls layout had been designed to accommodate a wide range of male and female crewmembers. The full 5th to 95th percentile range of male crewmembers could be accommodated, but for females the 35th percentile was the bottom of the range. Overall, the Comanche crewstation appeared to be more a descendant of a fighter aircraft than a conventional helicopter.

Electronics Architecture/Mission Computer Cluster

The electronics architecture was also highly advanced for a tactical aircraft, and although originally developed in the late 1980s, it had served the program well and provided for growth and flexibility to support changes and accommodate obsolescence. The core of the architecture was a centralized, modular mission computer cluster (MCC) that performed most of the processing for the system. The only system processing that did not occur in the mission computer was the flight control system

processing, which had its own dedicated and isolated, triple redundant computers. Residing within the mission computer cluster were a number of separate modules connected through a common backplane. The module types included: data processing, signal processing, graphics processing, video generation, bulk memory, data bus interface, data network switch, and power supplies. The subsystems were linked to the mission computer through a series of data busses ranging from a serially multiplexed Mil-Std 1553B for low data rate applications to several 1 gigabit, fiber channel, point-to-point fiber optic links for high bandwidth sensor data transfer. There were two mission computer cluster enclosures residing on opposite sides of the aircraft. The MCCs were redundant and capable of dynamically reallocating processing requirements. The modules were in the Standard Electronic Module E (SEM-E) format and incorporated very high density packaging of components. The modules were cooled by ECS air forced through the plenums in the racks. Through the development program, the modular processing had proven to work very well, often allowing for expanded capability by increasing the number of modules or upgrading individual modules with more capable components. Unfortunately, the basic processor, selected several years ago and resident on many of the modules, was an unpackaged Intel Pentium 233 Megahertz processor. This processor is no longer manufactured. Additionally, Intel no longer offers processors as unpackaged die. The Comanche MCC modules used many multi-chip packages (MCPs) that incorporated a number of die into the MCPs. At the start of the EMD program in 2000, the contractor team purchased the last remaining supply of Pentium 233 die. The quantity available supported the aircraft production program through aircraft eighty-nine. For aircraft subsequent to number eighty-nine, a new processing architecture was planned. Final decisions had not been made at time of termination, but the program was planning on selecting a Quad G-4 Power PC based processor and upgrading the fiber channel to 2 gigabit capability. Additional inter-processor bus changes were planned, and the card/module format was going to be changed to a [REDACTED] format.

The format change was necessitated by the inability to procure die. The size of current packaged processors does not readily support the SEM-E format.

Integration

Perhaps the most critical process in the program that was necessary to bring the full capabilities of the aircraft system to fruition was the integration of the large number of advanced technologies. They had to be brought together in a synergistic manner such that the capabilities of the platform greatly exceeded that of the individual systems and technologies. The integration allowed those unique skills and capabilities of the human crew to be optimized by the capabilities of the machine producing a synergistic result. The physical integration of the aircraft was well underway, but much work remained to be done. The Operational Flight Program (OFP) software releases were the mechanisms that brought functionality and capability to the aircraft. At the time of termination, OFP drop 10.4 which supported EOTADS and Night Pilotage functions on prototype two was nearing completion to support the late April flight. Also in work was OFP drop 11, which supported first flight of the EMD aircraft planned for June of 2005. The final planned OFP drop was drop 15, which was scheduled for completion in 2011. With drop 15, all the features and capabilities would have been in place. One highly advanced feature that was completed in this future release was the Tactics Expert Function. This function would assist the crew in making time critical decisions on how best to employ the aircraft while maximizing its survivability against a host of potential threat systems. Tactics Expert Function will be described in detail in another paper in this forum.

Technology Transfer

The direction provided by the Army Acquisition Executive in his Comanche termination guidance required the Program Manager to implement plans for the transfer or transition of Comanche technology to other Department of Defense (DOD) programs. Subsequently, the Project Manager (PM) directed the initiation of a

technology transfer program, resulting in the issuance of the partial termination notice to the contractor on 19 March 2004. The objectives of this technology transfer effort were to:

- Enable existing programs and platforms to leverage Comanche technologies for incorporation into their systems
- Ensure the proper balance was achieved between technology transfer and the return of residual Comanche funding to the Army for future aviation force use.

In order to achieve the above objectives, the PM established the following guidelines for the establishment and continuation of Comanche technology development and transfer activities:

- Any technology considered for transfer or continuation must have a platform host or sponsor.
- The Comanche PM will continue to fund technology transfer activities as part of the termination settlement through 30 September 2004.
- Sponsors must provide a logical plan for technology transition/integration and requisite funding for technology integration into identified platform beginning 1 October 2004.

The seven technologies listed below represent the original list of technologies that were to be carried forward for transition to other systems. Since the initial screening, the T802 engine initiative was terminated due to lack of sufficient program funding to complete the proposed technology transfer objectives.

- Image Intensified (I2) TV Camera
- Radar Electronics Unit (REU)
- Digital Fly-By-Wire Flight Control System (FCS)
- Radar Warning Receiver (RWR)
- T802 Engine (Now Cancelled)
- Integrated Communications System

- Communication System Antennas

Technology Transition Description

I2TV - At the termination of the Comanche program, a decision was made to continue the I2TV camera development to replace the Apache Arrowhead camera. The Apache A/D models have only a FLIR sensor in the Pilots Night Vision System. For the Arrowhead upgrade to the Apache TADS/PNVS, an I2TV camera will be added. The initial Arrowhead I2TV camera provided lower performance than the Comanche I2TV camera. In addition to the performance improvements, the Comanche I2TV camera is incorporating changes to eliminate the fiber-optic taper and providing larger pixel sizes for improved detector sensitivity. The Arrowhead program has determined the Comanche camera could better position them to meet their performance requirements.

Radar Electronics Unit

The Comanche Radar Electronics Unit combined the functions of the Longbow Radar Programmable Signal Processor (PSP) (90 pound box) and the Low Power Radar Frequency (LPRF) LRU (80 pound box) into a single unit weighing approximately 50 pounds. The REU functionally replaces both of these components while providing a number of technical improvements and address a major obsolescence issue. The Longbow Apache Block III program can significantly benefit from the reduced weight (120 pounds) and volume of the REU. The Block III program needs the volume for other new systems that are to be added. Under the phasing of the Comanche program, the REU had progressed to the point of preliminary design. The technology transfer objective is to continue the design of the REU through the end of Fiscal Year (FY) 2004, focusing on those areas of the design effort that are most beneficial to Apache. This would include the frequency exciter, software, mode development, and algorithms. Early in FY 05, the Apache Longbow Block III program will be able to pick up the remaining effort under their contract.

Digital Fly-By-Wire Flight Control System

At the termination of the Comanche Program, the Army was considering developing digital Flight Control Systems (FCS) for both the Apache and Blackhawk helicopters. The time frame for the desired implementation is 2007, which is a much accelerated schedule for developing and testing a new FCS. By leveraging the Comanche investment in funding and testing, both helicopters could benefit significantly. The Apache has a single channel mechanical flight control system and a back-up electronic flight control system (BUCS). The UH-60 Blackhawk has a dual, redundant mechanical flight control system. Both of these helicopters could benefit from the reduced weight and added reliability a digital fly-by-wire system would provide. Additionally, the improved handling qualities would result in significantly reduced pilot workload.

The Apache actuators are almost physically identical to the Comanche actuators and would require minimal modifications. The Blackhawk's components are not physically similar to Comanche's, but the architecture is readily adaptable to either the Apache or Comanche.

The Comanche FCS development is being continued as a part of the post Comanche technology transition to provide both Apache and Blackhawk an opportunity to leverage the investment. The technology transition plan calls for continuation of the generic portions of the Comanche FCS development through February of 2005 to allow both programs to award follow-on contracts that would continue the FCS's development and focus it on their specific aircraft.

Radar Warning Receiver

The Comanche Radar Warning Receiver was designed both to identify the full spectrum of radar threats and provide very high accuracy direction finding (angle-of-arrival) to threat emitters as well as to improve overall performance significantly. The primary reason for the performance improvement was the use of a digital receiver in lieu of the analog receiver used on previous RWR systems. In addition to

better performance the Comanche RWR was lighter and capable of detecting more threats than the Army's fielded RWR system, the AN/ APR-39. The other advantage of the Comanche RWR is the high accuracy direction finding capability which is only found in the Radio Frequency Interferometer (RFI) used as a part of the Longbow radar system on the Apache helicopter. The RF direction finding accuracy of the Comanche RWR (when used with appropriate antenna arrays) was very close to the accuracy of the Apache Longbow RFI.

By continuing the Comanche RWR development, Army aviation could obtain a modern, fully capable RWR that also has the capability of high accuracy direction finding. This new RWR could be used on many platforms in a kit form. Continuing the Comanche RWR development efforts through the end of FY 04 could provide the Army an opportunity to develop a program plan to leverage the Comanche RWR development activities in a follow on program and ultimately develop a high performance RWR system for all Army aircraft.

Integrated Communications System

The current plan is to transfer the Integrated Communications Navigation Identification Avionics (ICNIA) management to the Government as soon as possible. Continuing ICNIA development through the end of FY 05 would provide risk reduction for Army aviation and the JTRS Cluster 1 program. The specific details of this effort are continuing to evolve as the Comanche program works with the JTRS program to define an appropriate scope of work that could provide assets to the JTRS program and significantly reduce risk to that program.

Communications System Antennas

The current plan is for the FY 04 effort to continue through Jul 04 for qualification and first article inspection of the SATCOM Transmit, SATCOM Receive, Left UHF, Right UHF, Upper VHF, and 5 inch Lower IFF antennas. A potential technology transfer and use of the antenna technology

on the [REDACTED] Program has been initiated. The conformal lower IFF antenna has application potential in the larger aviation fleet to replace blade designs prone to ground strike.

Summary

The Army has invested several billion dollars in the Comanche program over the past 15 years. Much of this investment has gone into technology areas to support the Comanche mission requirements. With the termination of the program, it is the intent of the Department of Defense and Army to leverage these investment as much as practical and to provide technology support to other DOD programs. Additionally, the technology investment should be offered to other potential users where it supports the advancement of aviation technology. Only a few formal technology transition efforts are currently planned; however, the program office is attempting to provide the data developed in the Comanche program to the aerospace community where practical. The Comanche data is planned to be archived in a DOD sponsored library and made available to those who have appropriate authorization or clearance to use the data. It is expected that much of the data will be authorized for public access, but there will be restrictions where public release would be in violation of [REDACTED] and other security regulations.