The purpose of the digital automatic flight control system (Digital AFCS, DAFCS) is to decrease pilot workload by augmenting the flying qualities of the H-47 Chinook, thus making the aircraft easier to fly. DAFCS replaces the two existing analog controllers that currently reside on the aircraft with a pair of digital computers. Digital signal processing allows implementation of advanced control law algorithms with beneficial stability and control characteristics that decrease pilot workload. To minimize workload, the control laws allow the pilot to maneuver with ease and precision then hold the resulting flight condition without corrective inputs.

The DAFCS hardware and software were originally developed during development of the US Army CH-47F program in 2005 with a relatively minor update applied in 2007. The US Special Operations Command (SOCOM), which operates MH-47G Chinook aircraft, saw the benefits of the DAFCS and initiated a program to modify the existing flight control computer (FCC) software and add new control law algorithms. The new control laws are a direct response to the unique operational needs of their Special Operations heavy-assault flight crews. The upgraded MH-47G control laws achieved measurable and significant workload reduction in both maneuvering flight and steady flight. Whereas the CH-47F program abstained from forward-flight control law changes in order to meet an aggressive schedule, the MH-47G control laws are improved in all speed regimes. As a result of the control law modifications, both predicted and assigned handling qualities are improved for the MH-47G aircraft.

The MH-47G DAFCS program was conceived and born outside the normal U.S. Army rotorcraft procurement processes and created a unique challenge throughout program execution. Normal defense acquisition process involves the customer issuing requirements and the contractor returning a price to satisfy the requirements. However, at the time the MH-47G DAFCS program was initiated, there were already multiple international customers in the process of acquiring aircraft with DAFCS capability. In order to accommodate the benefits of these other development efforts and maximize the capability available to the MH-47G platform, the Technology Application Program Office (TAPO), the acquisition arm for SOCOM, entered into a cooperative research and development agreement (CRADA) with Boeing. While this agreement encouraged innovation by allowing limited-effort development without firm requirements being imposed, it also posed added complexity in the area of requirements and baseline management across programs.

The program overcame this challenge through the development of a robust technology development strategy that allowed for the spiral-development of capabilities. The MH-47G program took the lead in maturing the long-range DAFCS design, thus filling technology gaps and removing risk and compressing the schedules on other firm-fixed-price contracts. The direct application of the MH-47G DAFCS controls laws have already contributed to a 33% reduction in
DAFCS flight testing required for both the Canadian and Singapore development programs. In addition, the system demonstrated a solution for a current UK aircraft issue related to Roll Out Pitch Divergence (RPD) that has resulted in a significant UK program funding increase to incorporate the capability. Overall, the CRADA approach was indicative of the teaming that occurred between Boeing and TAPO throughout program execution. The cost and schedule baseline were shared and developed jointly between the teams. TAPO participated side by side with Boeing from the engineering development phase through flight testing, allowing the program to achieve the right balance of cost, schedule and risk, while maintaining the focus on a quality product for the end users. COL Patrick Mason, Project Manager of TAPO, summarized the effort by stating:

The MH-47G DAFCS Developmental Program illustrates excellence in execution. It began with an innovative cooperative research and development agreement from where we derived two key elements, a well crafted requirement and solid technical baseline. With this foundation, the team performed superbly and delivered exceptional system performance on cost and schedule. Most importantly, the 160th Special Operations Aviation Regiment was an integral part of every technical decision, conducted numerous early system evaluations and are extremely satisfied with what DAFCS brings to the aircraft. The DAFCS team lived our program office motto, “Deeds, Not Words.”

Throughout the DAFCS development phase, the most innovative control law design undertakings were permitted, with the understanding that they would be immediately aborted if significant challenges arose. This approach was agreed to by the customer to maximize the capability offered while mitigating the risk of not meeting mission objectives and maintaining cost and delivery schedule targets. In the end, every innovative undertaking that was pursued was ultimately proven successful. A prime example of such innovation is the elimination of sideslip differential pressure transducers. Since the H-47 first flew in 1961 (as the YHC-1B), every aircraft has used sideslip differential pressure feedback for augmenting directional stability. While the design team thought a replacement control law using lateral acceleration had great potential, they could not be absolutely certain that it would work. A "requirement" to develop it would have been rejected as too risky during a normal development program. However, by accepting the possibility of failure, the program allowed engineers to attempt the new control law and during flight testing the new design was validated. The elimination of this component reduces the cost, weight, maintenance and electrical usage for future aircraft, all while improving handling qualities and increasing the DAFCS system reliability.

During program initialization, the SOCOM customer identified three areas of DAFCS development that were critical to their mission performance; brownout landings, terrain following and aerial refueling. Each of these areas posed a unique engineering challenge that the team was able to overcome.
Brownout assault landings are a highly stressful event and landing gear are frequently damaged. The DAFCS reduces pilot workload and stress because releasing the controls results in a zero-velocity hover. The advancements of the MH-47G program improved CH-47F performance by extending the hover capture capability from 9 knots to 40 knots.

Terrain following involves flight in instrument meteorological conditions at 100 feet of altitude over rugged mountainous terrain. It requires the pilot to use both hands and both feet simultaneously to satisfy pitch, roll, and collective axis guidance cues at high pilot gain for prolonged time periods. The two-dimensional flight director cues do not provide foreknowledge of approaching terrain, so the pilot must include the raw radar returns in his visual instrument scan. Without DAFCS, terrain following is a two pilot job, with the copilot providing verbal coaching to the pilot by describing the situation ahead. In high workload terrain, pilots fatigue rapidly and are instructed to switch roles every 20 minutes to stay fresh. The DAFCS significantly decreases pilot workload and fatigue by reducing terrain following from a 4-axis task to a 1-axis task using only the left hand. Coupling the DAFCS pitch and roll axes to the flight director guidance cues allows the pilot to exit those control loops and assume a managerial role. DAFCS automatic trim eliminates pilot workload in the yaw axis as rotor thrust is constantly being adjusted. With DAFCS, the pilot adjusts collective with his left hand to satisfy the cue. The net result of DAFCS is a reduction in Handling Qualities Ratings (HQR's) for terrain following from a 5.5 (adequate - very high workload) to 2.3 (desirable - low workload).

Aerial refueling is another task unique to special operations. Pilots consider aerial refueling to be a high-gain task requiring aggressive yet precise control inputs from an uncoordinated flight condition. The close proximity to the tanker and need for fuel increase pilot stress. In turbulent air, adverse weather conditions, low power margin, and under intense pressure to perform, it is one of the most critically demanding tasks in aviation. With targeted control law enhancements to the pitch, roll, and yaw axes, DAFCS significantly decreases pilot workload during aerial refueling, resulting in an improvement to the Handling Qualities Ratings (HQR's) from a 5.8 (adequate - very high workload) to 2.4 (desirable - low workload).

In addition to the improvements to aircraft handling qualities and pilot fatigue, the team developed process improvements that will streamline all future control law development efforts. These process improvements focused on developing a piloted simulator, integration lab and linear analysis tools to allow increased refinement of the flight control law design before first flight. Compared with the original development of the DAFCS on the CH-47F, gain tuning efforts during MH-47G flight testing were reduced by more than 50% due to the increased maturity of the design resulting from the team’s enhanced use of development tools.

An added challenge to the MH-47G DAFCS program was the validation and flight test activity. Due to limited aircraft availability, the program was tasked with conducting a 180 hour flight test program within six months. Despite a historical average of five flight hours per week, the test team, which consisted of Boeing test pilots, flight test engineers, and flight engineers along with
Government test pilots and flight engineers, averaged seven productive flight hours per week over the entire six month test program. This represented a 40% improvement over historical flight test productivity rates and directly contributed to overall program success. These productivity rates were achieved while operating across the full spectrum of conditions. Operation was conducted initially during day visual conditions only and progressed into flight at night under night vision goggles for aerial refueling and all low speed tasks; including emulation of brown out operations. This high rate of productivity in such varied conditions was directly attributable to three factors. First, was the level of simulation conducted with the controls laws prior to flight test. As mentioned above, this level of fidelity in the lab enabled limited changes during flight testing. Second, was the baseline management process employed on the program. The strict management of the baseline design requirements as well as changes to the baseline enabled the team to not only enter flight test with a well-defined product, but also to effectively and efficiently deal with changes during the test program. The final impact to productivity was the management of the flight test team. The program manager identified a small team of dedicated individuals, clearly defined their roles, and ensured that there was no overlap in their responsibilities. This enabled the team to function at optimal efficiency, not just during testing but also in the area of maintenance, where the team did not lose a single day of testing due to maintenance activity.

Overall, the MH-47G DAFCS program applied the best analysis, design, and simulation tools and practices in the industry to realize program goals and deliver a successful product for their customer. Through diligent program management and oversight, the program was able to undertake the most innovative control law design activities while executing on-time and within budget to the program cost and schedule baseline. The combined government and contractor team was capable and empowered with a clear mission to provide operational pilots with the best possible product. The technical achievement and success in program execution were so significant that TAPO decided to accelerate the incorporation of DAFCS into their fleet of aircraft by two years. Their success in this mission can be clearly summarized by the comments of LTC Kevin Cochie, the director of the Systems Integration and Maintenance Office for SOCOM after evaluating the new control laws in flight: “I flew the aircraft Friday and was absolutely blown away with the performance. The entire Boeing crew on this project has demonstrated utmost professionalism to give us the capability we want out of the system. Joe Irwin, Jeffery Bender, and the whole crew have really represented your company well. This system is going to save lives and your guys should understand the impact they are going to have on Special Operations aircrews and our precious ground force.”
Patrick Donnelly is the Program Manager for all H-47 domestic programs including the CH-47D, CH-47F and MH-47G. He is responsible for the day to day execution for all development, manufacturing and delivery aspects of these aircraft.

Prior to this position Pat was the Director of Advanced Rotorcraft Systems for Boeing’s Phantom Works. He led a highly technical team in the research and development of all future rotorcraft. This work included not only technical enhancements of the current product line of Boeing rotorcraft: V-22, AH-64, H-47 and AH-6; but also the development of new systems such as the A160 Hummingbird, Skyhook, Future Transport Helicopter and Joint MultiRole.

Pat joined The Boeing Company in 1980 in the design group of the Boeing V/STOL Wind Tunnel and served in a variety of roles in engineering and support including manager, operations analysis (1984); senior manager Product Assurance (1986); manager, Tactical V/STOL Systems (1989); and Program Manager Proprietary Rotorcraft (1996). He has practitioner and/or management experience in mechanical design, operations analysis, weapon system integration, survivability technology, supportability and program management.

Pat holds a Bachelor’s degree in Mechanical Engineering from Rensselaer Polytechnic Institute, a Master’s degree in Mechanical Engineering from Cornell University and a Master’s in Business Administration from Widener University. Pat also completed the Advanced Program Management Course from the Defense Acquisition University at FT. Belvoir VA.

Mr Donnelly has strong leadership skills and proven ability to manage and motivate a team to achieve assigned results. His diverse background of disciplines makes him uniquely capable of managing all aspects of a program. The MH-47G DAFCS program was a great example of a well executed program that involved development, manufacturing, test and now production/fielding.
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