I. Program Overview

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<tr>
<th>Organization Name/Program Name:</th>
<th>BOEING MH-47G DAFCS</th>
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| Program Category | Sub-System R&D/SDD program or project |

**Program Background:** What is this program all about? (No more than one page). Describe:
- The overarching need for this program
- History of the program
- The product that is created by this program
- Scope of work – original & updated
- Expected deliverables
- Current status of the program

The purpose of the digital automatic flight control system (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 in 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.
I. **VALUE CREATION = 20 POINTS**

### Value:
What is the value, competitive positioning, advantage, and return created by this program to your:
- Customers – National interests, war fighter
- Company – Strength, bottom line, and shareholders
- Scientific/technical value (particularly for R&D programs)

### Excellence and Uniqueness:
What makes this program unique? Why should this program be awarded the Program Excellence Award?

### Customer Value:
The MH-47G heavy assault helicopter is a critical aviation asset in extremely high-demand, delivering special operations ground forces on target within +/-30 seconds anywhere in the world. The DAFCS is a direct response to the expressed operational needs of special operations flight crews to ease pilot workload and significantly enhance the safety, speed, and reliability of executing all heavy assault mission tasks. For example, brownout dust clouds during a landing approach can completely obscure the pilots' outside vision and lead to landing gear damage, a rollover mishap, or inadvertent flight into nearby obstacles or terrain. Even relatively minor landing gear damage can lead to casualties when fewer aircraft must cycle into the landing zone during exfiltration. Remarkably, pilots are more apprehensive of the dust than the tracer rounds coming at them! By offering an upgraded automatic hover capture-and-hold mode, DAFCS not only reduces pilot workload and stress but also diminishes the likelihood of damage and casualties.

Terrain-following flight and aerial refueling are elements of deep penetration missions. Without DAFCS, pilots must use both hands and both feet simultaneously for prolonged time periods with pilots switching roles every 20 minutes to stay fresh. With DAFCS, terrain following is reduced to a single-axis task using only the left hand, resulting in a 57% improvement to pilot workload. Aerial refueling behind a C-130 tanker involves the MH-47G pilot guiding the tip of a rigid probe into a paradrogue just 2 feet in diameter while in close formation less than 100 feet apart at 110 kts. At night, in turbulent air, adverse weather conditions, and under intense pressure to perform, it is one of the most critically demanding tasks in aviation. DAFCS is the first system to offer control laws specifically designed for aerial refueling, driving a 63% improvement to pilot workload. These improvements in situational awareness and decreased workload assist in reducing the number of mishaps caused by human factors, which in recent years have caused approximately 80% of U.S. military rotorcraft losses. The total non-recurring cost to develop DAFCS for the MH-47G is approximately 1/4th the replacement cost of a single helicopter. DAFCS retrofit costs are approximately 1/100th the replacement cost of a single helicopter, while being more reliable and easier to...
Company Value: The continued development of DAFCS creates added demand for the Chinook. The MH-47G DAFCS program has eliminated technical risk in the form of a 33% reduction in flight test requirements for two current international customers. Further, the technology developed is presently being sold to the U.S. Army for the CH-47F and other international customers. Overall, the MH-47G DAFCS program will result in a upcoming sale of retrofit kits to implement on the fleet of MH-47G aircraft as well as increased opportunity for sales of large tank aircraft to international customers.

Technical Value: During development, the DAFCS system demonstrated a solution for a current UK aircraft issue related to Roll Out Pitch Divergence (RPD). This demonstration has resulted in a significant UK program funding increase to fully incorporate the capability on their platform. Overall, DAFCS is the only system in the world to offer the advanced brownout solution control laws without a costly full-authority fly-by-wire architecture. The H-58 and H-60 are now following the lead of DAFCS.

Excellence: In the words of TAPO project manager, COL Patrick Mason, “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.”

Strategic: Opportunity Management - Describe how your program has identified its operational and business opportunity, and manages this opportunity throughout the program’s life cycle.

Towards the end of 2007, multiple domestic and international armed forces were pursuing DAFCS in long-range Chinook variants. These unique market conditions produced a business case which enabled the Technology Application Program Office (TAPO), the acquisition arm for SOCOM, to enter into a cooperative research and development agreement (CRADA) with Boeing. This agreement encouraged innovation by allowing limited-
effort development without firm requirements being imposed. The opportunity was fostered and evolved into a cost-plus-fixed-fee contract by demonstrating the value of the technology to the customer through simulations and demonstration. This level of collaboration continued throughout execution, and has contributed to the acceleration of the fielding of the retrofit units.

**Strategic:**
Strategic Supply Chain Integration and Cost Effectiveness Management: Describe how your program is integrating its supply chain to assure visibility and adapting long-term cost effectiveness up and down the supply chain.

The DAFCS program utilized one subcontractor, Rockwell Collins, who was critical to integrating the solution into the existing cockpit management system. In order to ensure the proper systems integration, a single statement of work containing both the contractual and technical requirements was used. Further, the engineering team was relied upon to conduct a thorough technical evaluation of the proposal prior to awarding a contract. On a monthly basis, management received status reports that addressed technical topics, upcoming reviews and milestones and risks and issues. These reviews also tied in cost and schedule status to ensure adequate progress. In the end, the extra work prior to contract award ensured a fully compliant technical solution that was delivered under budget, allowing for opportunity to add capability during the testing and airworthiness review cycles.

**Strategic:**
Operational Integration and Systems Engineering – Describe the challenges faced by your program in terms of integrating the system into its operational environment and its impact on systems engineering planning and management.

The MH-47G DAFCS program was a true systems integration effort, with activities spread across multiple organizations. While Boeing was prime for development of the design solution, TAPO contracted directly with L3 to complete all hardware modifications. To ensure successful integration, Boeing provided L3 with a detailed interface document. Then as design activity commenced, Boeing and TAPO both participated in bi-weekly teleconferences with L3 to work through any drawing questions or issues that arose. Once the DAFCS changes were installed, the next challenge was how to ferry the aircraft to Boeing even though the new control laws with DAFCS were not cleared for flight. To overcome this challenge, Boeing allowed for the legacy gains in the control laws, which were cleared for flight, to still be active allowing for a safe configuration of the software to be flown prior to developmental flight testing. Other design issues were encountered during flight testing. In order to mitigate these issues and limit impact to the program schedule, Boeing coordinated a plan to work together with the Army Engineering Directorate (AED), to allow them to witness testing on-site. This approach,
which was defined prior to execution based on previous lessons learned, resulted in minimal time being required for documentation review and final approval of an airworthiness release.

| Operational: Planning, Monitoring, and Controlling - | The MH-47G DAFCS program was structured with a single Integrated Product Team (IPT) at Boeing coordinating the majority of the development effort. This IPT was closely aligned with TAPO counterparts, resulting in a joint team executing the effort. This team worked together to build an overall master plan and schedule for execution, with milestones defined with clear expectations for success. With an aggressive program schedule that required completion of flight testing by a firm date, TAPO was also included in the weekly management of program activities. The program manager monitored cost and schedule performance on a weekly basis, with TAPO having full insight into weekly performance. This allowed for the joint Boeing/TAPO team to quickly mitigate issues or delays as they came up. An example of this was during flight testing, when the team agreed to enter the aircraft into phased inspection early to avoid weather delays, thus allowing the aircraft to re-enter testing once the poor weather lifted. |
| Supply Chain and Logistics Management -- | The team utilized internal Supplier Data Transmittal (SDT) tool to receive, review and disposition data deliverables through the lifecycle of the program, ensuring robust integration throughout the development cycle. Rockwell Collins and Boeing coordinated as a single team through monthly status reports, weekly technical teleconferences and program reviews. Upon receipt of the Rockwell Collins proposal, the technical team reviewed the basis of estimate to ensure the tasks and hours proposed aligned with each item in the work breakdown structure, thus ensuring a fully integrated technical solution. This collaboration between the supplier management and technical teams resulted in open communication lines and a simpler path towards integrating the Rockwell Collins solution. |
| System Integration, Testing & Reviews - | The program was executed primarily by a single IPT, with close alignment with the TAPO customer, resulting in a team that was right-sized and sole tasked to accomplish development of the MH-47G DAFCS. This level of coordination allowed for successful integration of the software and hardware design solutions. The joint team reviewed progress weekly. At the appropriate times, the program conducted a Preliminary and Critical Design
**MH-47G DAFCS**

**Operational:**  
**Risk / Opportunity Management**  
Describe the processes used to identify both risks and opportunity and to assure potential for both is addressed effectively. Please indicate any forward-leaning processes to support.

The DAFCS program uses a structured process and a well defined, Boeing-wide tool called BORIS (Boeing Opportunity Risk & Issue System) to manage risk and opportunities. Program risks, as well as opportunities are identified and then defined in terms of likelihood and consequence. Mitigation plans are then established for a step-by-step reduction/improvement of both indices. During the program, all identified risks were mitigated to a low status and none were realized. In order to offset that risk, several opportunities were identified. Even though they increased the overall scope of the effort, several were pursued and realized with no cost or schedule impact to the program.

**Team Leadership:**  
**Team Culture and Motivation**  
Describe how you created your team spirit and culture, and accomplished entire team integration and individual team member motivation.

From the beginning of the program, the positive impact of the potential improvements to the MH-47G operational utility sparked a can-do team culture that fostered strong working relationships at the individual, team, and customer level. Motivation was enhanced at each milestone; as the team would review technical performance and schedule to reestablish buy-in for future goals, as a team, and then set a path forward. Each member of the team was empowered and understood their value and impact on the team’s performance and success. The culture of empowerment and a shared vision for team success drove the overall success of the team.

**Team Leadership:**  
**Lessons Learned and Knowledge Management**  
Describe how you collect lessons learned and best practices, and how they are shared with your team and company to improve performance. Also how are you capturing expertise and knowledge to assure availability over the life of the program?

There are many process and procedures for the collection and interpretation of lessons learned; however, for the team to benefit from the observations of the ongoing activity, a methodology of timely self review was required. While continued contribution to the normal company process was conducted; simultaneously, extracts of daily activity were recorded and stored informally at the individual teaming level. This allows for quick review of test methods, communication techniques, scheduling philosophies, and establishing priorities on a recurring basis. During transition from test event to test event, as a team, a review was conducted of particular requirements and goals of the test phase. These expectations were vetted against lessons learned and improved methodology of moving forward was created. New team members could quickly be added for review of formal documents.
and then a quick desk side brief detailing the informal data summary.

| Team Leadership: | By virtue of the programs cooperative product development structure, the DAFCS team was able to increase their technical skill through the increased design freedom and higher technical risk. In addition, the program manager permitted the team to operate with a level of autonomy, allowing for them to undertake increased responsibilities. They were then fostered through guidance, monitoring and mentoring, which occurred on a recurring basis via formal and informal team progress reviews. |
| Leadership Development | How do you develop team’s skills and build future leaders |
| **Best (& Next) Practices:** | The MH-47G DAFCS program utilized a cooperative research and development approach as a best practice to achieve success. Through this approach, the Boeing team was able to capitalize on its design freedom and maximize its product enhancement opportunity, accepting higher technical risk early in the program. However, true success was achieved by truly integrating the customer, including the end user, into the team. This partnership enabled the right system requirements to be clearly understood, and led to a superior system being produced at a lower cost. While software development and systems engineering documentation was maintained, it was done as a by-product of the innovation and design freedom of the team; not as the driver of the program. |
| Identify your program’s specific Best Practices that you believe are unique, and could be shared with others and become industry’s Next Practices. | |

IV. ADAPTING TO COMPLEXITY: (HOW DO YOU DEAL WITH YOUR PROGRAM’S UNIQUE COMPLEXITIES) = 20 POINTS

Identify the Program’s Market Uncertainty level – How new is your product to your market and users, based on the definitions below. Then describe how you deal and address this specific uncertainty:
- **Derivative** – an improvement of an existing product/system.
- **Platform** – a new generation in an existing product line.
- **New to the Market** – a product or system adopted from another market.
- **New to the World** – breakthrough product.

The MH-47G DAFCS is a derivative of the CH-47F DAFCS and contains new-to-the-world control law technology. The highly-evolved MH-47G DAFCS control laws are well-adapted to satisfy special operations mission requirements of today's environment and in the future. These sometimes unusual missions consist of similar sub-tasks, such as managing closure rate on a target. The commonality with CH-47F allowed systematic categorization by the demands placed upon the pilot. These tasks include evasive maneuvers, formation flight with both friendly and enemy air/sea/land vehicles, stable hover in zero-visibility conditions, and basic maneuvering. Because the DAFCS was optimized to the pilot tasks, not today's specific missions, the optimization will remain relevant as new mission tasks emerge in the highly-dynamic combat environment of special operations aviation.
Identify the Program’s Technological Uncertainty using the definitions below. Then describe how you deal and address this uncertainty:
- **Low-tech**: application of mature, well-established technology
- **Medium Technology**: existing technology modified to meet new design requirements
- **High-Technology**: recently developed new technology
- **Super High-Technology**: non-existing technology that needs to be developed during the program.

Some of the breakthrough control law technology was developed during the program and therefore meets the definition of super high-technology. Before MH-47G DAFCS, no research was conducted on flight control requirements for helicopter aerial refueling. During the MH-47G DAFCS program, three aerial refueling mission task elements (MTEs) and performance standards were defined to provide a framework for measuring improvement. The Boeing Flight Simulation Lab was upgraded to provide the visual cues necessary for the MTEs. The simulator was heavily employed for rapid prototyping and selection of control response types prior to flight test. Finally, linear analysis was used to rapidly assess specification compliance and metric sensitivity to gain adjustments. By using the simulation and analysis tools to their maximum effectiveness, the scope of flight testing was reduced by 40%. Pilot ratings improved from borderline unacceptable to satisfactory and good.

Identify the level of your System Complexity using the definitions below. Then explain how you are dealing with this level of complexity:
- An **Assembly** performing a single function.
- A **Sub-system** fitting within a larger system.
- A **System** – a collection of subsystems performing multiple functions.
- An **Array** – a “System of Systems”; a widely dispersed collection of systems serving a common mission.

The MH-47G DAFCS is a system which interfaces with the onboard navigation sensors, the human operators, the highly-integrated Common Avionics Architecture System (CAAS), and a suite of hydraulic and electrical actuators. Flight control system complexity must be carefully managed to avoid uncommanded inputs that can lead to loss of control, loss of the helicopter, and loss of life. Because DAFCS is a mix of dual-redundant and single-redundant subsystems, complexity is significantly increased.

The DAFCS complexity is actively managed by process controls during design, code, and test activities. The software is compliant with DO-178B Level A standards, with requirements documented in system/subsystem specifications and rigorous lab testing for closed-loop system verification. The software is subdivided into manageable segments, with each possessing limited authority to assist in evaluating issues.

Identify the Pace and Urgency of your team’s effort using the definitions below. Then describe how you deal with the program’s pace requirements:
- **Regular timing** – no specific time pressures.
- **Fast/Competitive** – time to market is important for competitiveness.

DAFCS development was time-critical because of the high operational tempo and mishap-rates in operations around the globe. Rigid cost and schedule requirements were mitigated with flexible system requirements. Throughout the 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.
- **Time Critical** – there is an absolute and critical-to-success deadline.
- **Blitz** – there is a crisis element driving the need for immediate response

targets. Cost and schedule were continuously managed using weekly progress reports and continuous open communications between the customer and contractor. In the end, the program success has created such a high demand for the product that the operational fielding of MH-47G DAFCS has been accelerated by 2 years.

**Other Complexities & Uncertainties**
Describe other complexities and unknown factors faced by this program and how you addressed them.

The MH-47G DAFCS program faced development complexity with the enhancement of aerial refueling performance. A key feature which enhances aerial refueling is the elimination of sideslip differential pressure transducers. Since the H-47 first flew in 1961, sideslip differential pressure feedback has been used to augment directional stability. Removing the air pressure transducers improves platform stability and reduces system complexity, weight and cost while simultaneously improving reliability and maintainability. However, removal added significant technical risk in the form of control law design complexity. It also required clear communication and coordination with the user, to ensure their buy-in to operations of the aircraft without this legacy component.

V. METRICS (HOW DO YOU MEASURE PROGRAM’S PERFORMANCE) = 30 POINTS
(Note: We are not looking for $ results, but the relative percentage achieved. In particular indicate what specific metrics and data you are using that drive the program beyond standard measures of schedule, budget, and performance, and which have contributed to your program’s focus and its success.)

**Customer** - How do you measure the impact of your program on your customer and your customer’s satisfaction? Include a description of your metrics, as well as numerical evidence.

The customer was an integral part of the team, and their inputs were gathered throughout execution. The program manager conducted weekly tag-up discussions with the customer program manager to ensure their satisfaction with the overall direction of the program and to review key metrics including Earned Value Management (EVM), schedule performance and current program risks and issues. The satisfaction of the customer is clearly evident in the words of LTC Kevin Cochie, Direction of the Systems Integration and Maintenance Office (SIMO), who stated "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."

**Performance** - How do you measure your program’s performance in traditional terms such as

The MH-47G DAFCS program utilized standard EVM to assess the program performance. This technique integrates the work scope, cost and schedule with the company policies
### Schedule, Budget, Requirements, and Business Results?

and procedures that are in place to manage work. Through this process, the program reviewed the performance data on a weekly basis, and shared this data with the customer. This level of collaboration allowed for the Boeing and customer leadership to regularly assess the technical, cost and schedule performance and make critical decisions in a timely manner to ensure overall program execution.

### Preparing the Future -

**How do you measure and assess the long-term contribution of your program to the corporation/organization?**

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 MH-47G system demonstrated a solution for a current UK aircraft issue that has resulted in a significant program funding increase by the UK to incorporate the capability. In the end, Boeing will field this system not only for the 160th Special Operation Regiment, but also for three international customers. Further, the capabilities developed offer future opportunity to upgrade the existing US Army CH-47F system.

### Team -

**How do you measure and assess the impact of your program on your team development and employee satisfaction?**

The impact of the MH-47G DAFCS program on the team that executed the work is clearly evident through recognition received internally and externally. The efforts of this team have been recognized by the TAPO customer in a formal setting. Further, the team has been recognized internally by the Boeing Company for their technical contributions. Individually, the impact of this program on employee development is clearly demonstrated in recent recognition for the program’s lead engineer, who was recently named “Engineer of the Year” by the Boeing Company for the of Defense, Space and Security business.

### Unique Metrics -

**Describe any unique metrics you are using to measure your program’s progress and how do you focus it for outstanding success.**

The MH-47G DAFCS program utilized unique metrics to drive exceptional performance during flight testing. The team linked their schedule and flight hours to specific achievements/inchstones. This tight coupling of information enabled management to quickly determine risk levels and allocate additional resources as necessary. They provided the team with exceptional visibility and enhanced their decision-making, enabling them to increase flight test efficiency by 40% against historical performance.