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Global Hawk: Root Cause Analysis of Projected Unit Cost Growth

Jeffrey N. Fox
Paul M. Kodzwa
David M. Tate, Project Leader
Patricia F. Bronson, Task Leader

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About This Publication

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Executive Summary

Task Description

In May 2010, Office of the Principal Deputy Under Secretary of Defense (Acquisition, Technology and Logistics) asked the Director, Performance Assessments and Root Cause Analyses (PARCA) to perform a root cause analysis of anticipated unit cost growth in the Global Hawk unmanned aircraft system (UAS) program. This request was based on a fast-turnaround cost estimate performed by CAPE-CA, the cost analysis group within the Cost Analysis and Program Evaluation (CAPE) directorate of the Office of the Secretary of Defense. That cost estimate concluded that average procurement unit cost (APUC) for the Global Hawk program has grown by more than 20 percent since the program was rebaselined in 2007, following a critical Nunn-McCurdy breach in 2006.

PARCA asked the Institute for Defense Analyses (IDA) to identify the root causes of the APUC growth identified by CAPE-CA, in accordance with the root cause analysis guidelines established in the Weapon Systems Acquisition Reform Act of 2009 (WSARA). This report describes our task analysis and findings.

The Global Hawk Program

Global Hawk is a family of high-altitude, high-endurance UASs carrying a variety of intelligence, surveillance, and reconnaissance (ISR) sensors. The current program is developing, producing, and supporting four distinct increments, or “blocks,” described in the following table.

Global Hawk Block Descriptions

Increment	Air Vehicle	Payload (lbs)	Delivered To Date	Future Quantity	Sensor(s) Carried
Block 40	RQ-4B	3000	1	21	Multi-Platform Radar Technology Insertion Program (MP-RTIP) Radar
Block 30	RQ-4B	3000	5 (1 with ASIP)	37	Airborne Signals Intelligence Payload (ASIP) & Enhanced Integrated Sensor Suite (EISS). EISS contains an improved version of EO (Electro-Optical)/IR (Infrared) sensors and SAR (Synthetic Aperture Radar)
Block 20	RQ-4B	3000	6	0	EISS
Block 10	RQ-4A	2000	7	0	Integrated Sensor Suite (ISS). ISS contains EO/IR sensors and SAR)

While the Global Hawk program has been a major defense acquisition program (MDAP) since 2001, the current program is defined by an Acquisition Program Baseline (APB) established in 2007, as a result of a critical Nunn-McCurdy breach for cost and schedule. The defining documents for the rebaselined program are:

- Capability Development Document (CDD)
- Cost Analysis Requirements Description (CARD)
- Test and Evaluation Master Plan (TEMP)
- Acquisition Program Baseline (APB)
- Acquisition Strategy Report (ASR)

The original Global Hawk program was envisioned as a spiral development effort, developing and modifying both aircraft and payloads over time. Payloads of interest (including some developed outside the Global Hawk program) were to be integrated onto the Global Hawk platform as they became sufficiently mature. As a result of cost growth and schedule slip in the program, the 2007 APB restructured the program to have fixed content and completion criteria as defined by the new CDD, CARD, TEMP, and ASR. The four increments shown in the table above reflect the baseline content of the program as established in the APB via these documents. All Block 10 aircraft had been delivered at the time of the APB, and an Operational Assessment was completed in March 2007, but operational test and evaluation activities on Block 10 were still in process. As of the December 2009 Selected Acquisition Report (SAR), an Initial Operational Test &

Evaluation ("IOT&E Phase II") was planned for July–October 2010. The program is now essentially developing and fielding three highly common yet significantly different UASs in parallel.

The CDD requirements for these remaining blocks have associated due dates, with specified performance requirements for each block becoming more stringent over time. A requirement with an explicit date is considered to be part of the baseline program content. The CDD also includes "undated" requirements, stating capabilities of interest that are not part of the baseline program content, and thus not within the scope of the CARD or TEMP.

Root Cause Analysis Performed

Prior to the CAPE-CA May 2010 estimate, the Global Hawk program office also provided an estimate of procurement cost growth in the December 2009 SAR. We collated the areas of cost growth identified in these two estimates, and aligned them to the extent possible. Based on this alignment, and discussions with the CAPE-CA cost analysts, we developed a combined estimate that represents a unified picture of estimated procurement cost growth since the 2007 APB. We then performed a root cause analysis on the cost growth areas of the combined estimate.

The root cause analysis was done in two stages. First, we identified causal factors that led to the identified cost growth. We then aligned those causal factors with the WSARA taxonomy of root causes:

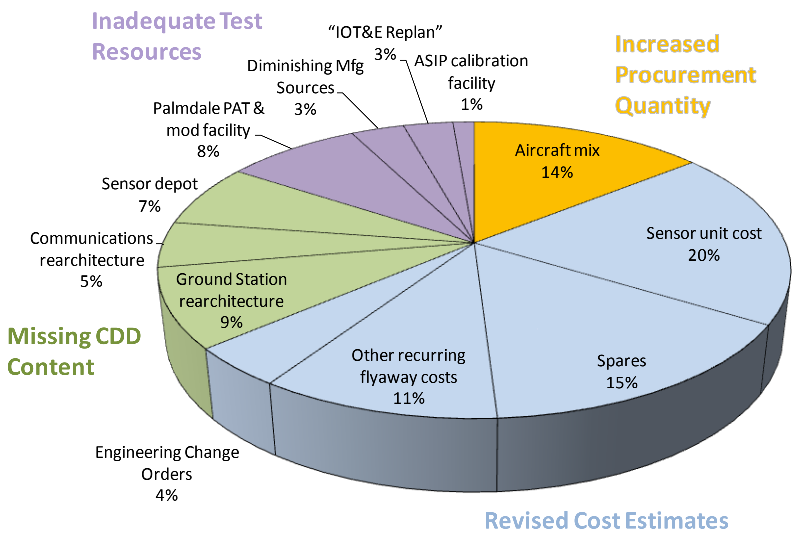
1. Unrealistic performance expectations;
2. Unrealistic baseline estimates for cost or schedule;
3. Immature technologies or excessive manufacturing or integration risk;
4. Unanticipated design, engineering, manufacturing, or technology integration issues arising during program performance;
5. Changes in procurement quantities;
6. Inadequate program funding or funding instability;
7. Poor performance by government or contractor personnel responsible for program management; or
8. Any other matters.

Findings

The procurement cost growth quantified in the combined estimate falls into four primary areas. These areas are:

- Changes in aircraft mix, resulting in procurement of a higher proportion of Block 30/40 aircraft
- Upward revision of APB cost estimates for sensor payloads, initial spares, and many “below the line” cost elements
- Belated recognition of baseline program content that was missing from the APB estimate
- Costs incurred to mitigate a lack of adequate test resources

The assignment of cost growth to these areas, with the relative contributions to APUC growth, is shown in the figure below.



Relative Contribution of APUC Growth Areas

We traced these factors to five primary root causes from the WSARA taxonomy. In priority order, they are:

- Poor performance by the government and contractors,
- Unrealistic cost and schedule estimates,
- Unanticipated technical issues during program execution,
- Inadequate program funding, and
- Increased procurement quantities of the more expensive Global Hawk variant.

The full details of the facts and reasoning behind these attributions are given in the main body of this report. A description of each factor is included.

Conclusions

Overall, APUC growth in the Global Hawk program has had many intertwined causes. It is essentially impossible to allocate specific amounts of APUC growth to specific root causes, due to the interactions among the various shortcomings of program execution, contractor performance, baseline estimates, baseline schedule, Air Force oversight, Air Force funding approaches, and program content definition. Of these shortcomings, the unexecutable schedule, missing program content, and (to a lesser extent) unrealistic baseline cost estimates were knowable at the time of the 2007 APB and thus represent "birth defects" of the rebaselined program. Failures of contractor execution, program management, and Air Force oversight and funding approaches are "nurture" shortcomings, which might have been avoided even given the flawed APB. However, the flaws built into the APB—particularly the unexecutable schedule—also made certain problems of execution significantly more likely than they would have been otherwise.

At the highest level, we conclude that a lack of accountability in the government management chain and a poor alignment of incentives with desired outcomes were overarching contributing factors to the cost growth identified (and to other ongoing program issues). We also identified several areas of potential additional cost growth in the future. The main areas of future concern (discussed in the body of this report) are:

- Date-specified CDD requirements not yet included in program execution planning or budgeting,
- Additional schedule delays due to program concurrency and increasing external factors,
- Costs to fund and execute a reliability growth program and associated rework/retrofits,
- Additional unit cost growth of the MP-RTIP and (to a lesser extent) ASIP sensors, and
- Additional support funding after FY 2018.

Contents

A. Introduction

In May 2010, Mr. Frank Kendall, the Principal Deputy Under Secretary of Defense (Acquisition, Technology & Logistics (AT&L)), asked the Director, Performance Assessments and Root Cause Analyses (PARCA) to perform a root cause analysis of anticipated unit cost growth in the Global Hawk unmanned aircraft system (UAS) program. This request was based on a fast-turnaround cost estimate performed by CAPE-CA, the cost analysis group within the Cost Analysis and Program Evaluation (CAPE) directorate of the Office of the Secretary of Defense (OSD). That cost estimate concluded that average procurement unit cost (APUC) for the Global Hawk program has grown by 23 percent since the program was rebaselined in 2007, following a critical Nunn-McCurdy breach in 2006.

In June 2010, PARCA asked IDA to identify the root causes of the APUC growth identified by CAPE-CA. This report describes IDA's analysis and findings related to that task. IDA briefed these findings to PARCA leadership in August 2010. This analysis supports PARCA in their root cause analysis role, in accordance with the root cause analysis guidelines established in WSARA section 103.[1]

B. The Global Hawk Program

1. System Description

The Global Hawk RQ-4A/B, shown in Figure 1,[2] is a high altitude, long endurance UAS designed to provide Intelligence, Surveillance, and Reconnaissance (ISR) through its Integrated Sensor Suite (ISS) payloads. Global Hawk has been providing ISR for several operations in the Global War on Terror (GWoT), including Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). As of February 2010, Global Hawks had flown over 30,000 combat hours in support of the above operations. In addition to the U.S. Air Force program addressed in this report, Global Hawk variants have also been ordered by the U.S. Navy (RQ-4N, which will be the platform for the Navy's Broad Area Maritime Surveillance (BAMS) program) and Germany (EuroHawk, a derivative of the Block 20 Global Hawk). Additionally, the National Aeronautics and Space Administration (NASA) currently operates two RQ-4A aircraft out of Dryden Flight Research Center for conducting atmospheric research. In 2007, the North Atlantic Treaty

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1 *Weapon Systems Acquisition Reform Act of 2009*, Public Law 111-23, Section 103, May 22, 2009.

2 U.S. Air Force Master Sgt. Robert Holland, left, briefs a group of airmen deployed from Schriever Air Force Base, CO, and assigned to the 380th Air Expeditionary Wing, about the RQ-4 Global Hawk unmanned capabilities in Southwest Asia, Oct. 12, 2006. U.S. Air Force photo by Master Sgt. Jason Tudor. http://www.defense.gov/transformation/images/photos/photo_archive/index_2006-10.html.

Organization (NATO) selected a modified RQ-4B as the air component of NATO's Alliance Ground Surveillance (AGS) system.

Figure 1. RQ-4 Global Hawk

Global Hawk is actually several simultaneous development programs, with several aircraft variants and payloads (known as "blocks") being developed simultaneously and deployed as they are ready. The current program consists of Blocks 10, 20, 30, and 40. For purposes of SAR unit cost computations, the "quantity" for the program is the total number of Air Force Block 10/20/30/40 aircraft. It does not include prior variants (Block 0 and Block 5) that were developed and fielded as part of the original Advanced Concept Technology Demonstration (ACTD) program, and it does not include aircraft produced for the Navy or for foreign military sales (FMS).

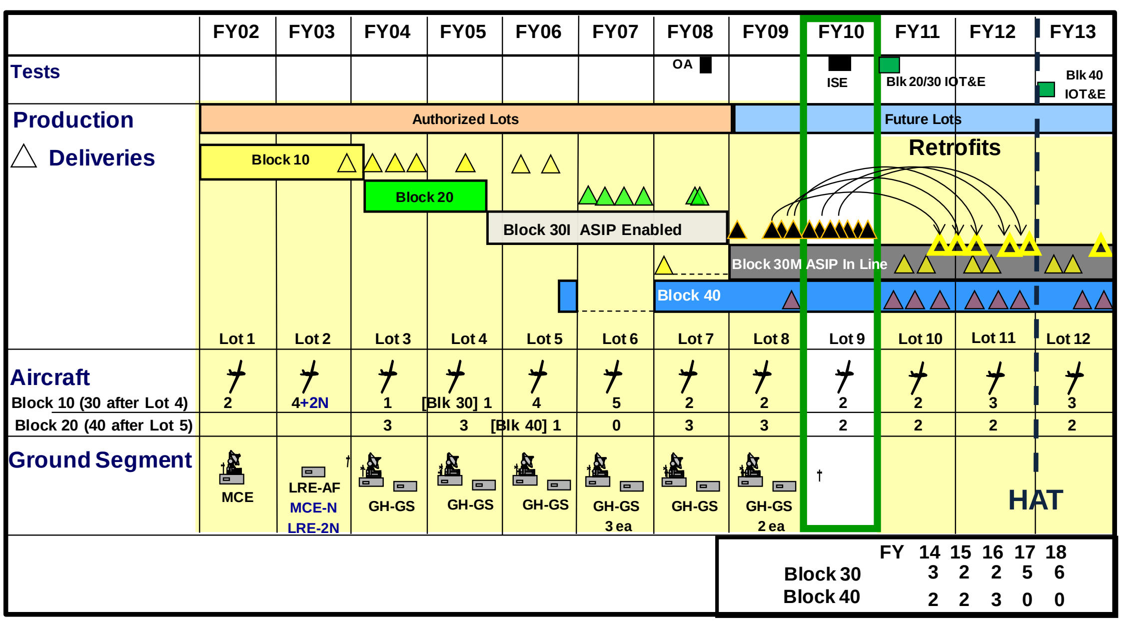
Block 10, based on the RQ-4A aircraft with a 2,000 pound maximum payload, carries a basic ISS with Electro-Optical (EO) and medium-wave Infrared (IR) imagery capabilities, as well as a high-resolution digital Synthetic Aperture Radar (SAR). Block 10 is the only operational military Global Hawk increment at present. This is the configuration that has flown tens of thousands of mission hours in Iraq and Afghanistan.

Blocks 20, 30, and 40 are based on the larger RQ-4B aircraft with a 3,000 pound maximum payload. Block 20, also designed for image intelligence (IMINT), carries the Enhanced Integrated Sensor Suite (EISS), which has increased range and resolution as compared to the ISS. Only 6 Air Force Block 20 aircraft were produced, but the Navy BAMS program plans to procure at least 50 modified Block 20 aircraft.

In 2005, Secretary of Defense Donald Rumsfeld issued Program Budget Decision 720, which directed the retirement of several older aircraft, including the U-2 Dragon

Lady. The 55-year-old U-2 program provides high altitude multi-INT collection capability, including signals intelligence (SIGINT) and either optical camera photography, EO/IR imagery, or SAR. After much discussion and debate within and between the Air Force and OSD, Lt. Gen. David Deptula, the Service's deputy chief of staff for ISR, established a High Altitude Transition (HAT) plan in 2006. Under this plan, the Global Hawk Block 30 would replace the U-2, which would be retired. A tentative schedule for this transition was established, but with the proviso that U-2 retirement dates were to be considered targets and not deadlines. Congress reinforced this proviso with language in the 2007 National Defense Authorization Act that required the Secretary to certify that retirement of the U-2 would not create any intelligence gaps prior to retiring any of the aircraft.

The Block 30 Global Hawk will provide SIGINT capability by integrating the ASIP, originally developed by the ASIP program. Since production of Block 30 began prior to the development of ASIP, there are currently two Block 30 variants: Block 30I, which is equipped for future ASIP installation but does not carry the sensor, and Block 30M, which will have ASIP installed "in-line" at the time of initial production. At the time of this report, the Global Hawk program plans to retrofit 11 Block 30I aircraft with ASIP, with 9 aircraft delivered in time for a planned 1QFY13 HAT shown in Figure 2.



Note that Block 10 aircraft were not produced after Lot 3 and Block 20 aircraft were not produced after Lot 4. These rows in the above table are replaced with numbers for Block 30 and Block 40 aircraft, respectively. Also note the breakup of Block 30 into the ASIP Enabled Block 30I and ASIP in-line Block 30M aircraft.

Figure 2. Global Hawk Production Buy Schedule Based on FY 2011 PB

Finally, Block 40 Global Hawk will carry the MP-RTIP radar as its only sensor. This radar will provide both SAR capabilities (spot and strip/mapping) and Ground Moving Target Indication (GMTI) concurrently. MP-RTIP was developed and reported within a separate MP-RTIP MDAP, reaching Milestone B in October 2003. This program was responsible for both the MP-RTIP, to be integrated onto both Global Hawk and the E-8 Joint STARS aircraft, and for a larger variant of MP-RTIP for Wide Area Surveillance on the E-10A. The E-10A was cancelled in 2006—making Global Hawk now the only platform intended to use the MP-RTIP—and responsibility for development and integration of the radar has been shifted from the cancelled MP-RTIP program to the Global Hawk program. MP-RTIP is currently being tested on the Proteus test-bed aircraft, with incorporation onto the RQ-4B to follow.

2. History of the Global Hawk Program

The Global Hawk program began in 1994 as part of the Defense Advanced Research Projects Agency's (DARPA) High Altitude Endurance (HAE) Unmanned Aerial Vehicle (UAV) project, with Teledyne Ryan winning the contract to develop an ACTD. Northrop Grumman acquired Teledyne Ryan in 1999, and took over the contract and subsequent work on Global Hawk. In March 2001, the Defense Acquisition Board (DAB) issued an Acquisition Decision Memorandum (ADM) announcing the transition from ACTD to Engineering and Manufacturing Development (EMD) and, unusually, the beginning of Low Rate Initial Production (LRIP). Subsequently, the first LRIP contract was awarded to Northrop Grumman in January 2002 to produce two Block 10 RQ-4A aircraft.

In 2002, due to high demand for Global Hawk's reconnaissance capabilities, the program office and contractor chose a spiral development program for Global Hawk consisting of six developmental spirals built around a single EO/IR/SAR and SIGINT configuration. This would facilitate deployment of earlier configurations of Global Hawk while continuing development of more advanced capabilities. Nineteen air vehicles and 10 ground stations were ordered at this time. In August 2003, the contractor completed the first RQ-4A from LRIP Lot 1. Global Hawks completed under ACTD as well as the Block 10 aircraft completed under the first LRIP contract were deployed to support both OEF and OIF. The development and production of these early configurations were subsequently accelerated to meet growing operational needs (particularly in OEF), leading to delays in upgrading earlier produced units.

Starting in 2003, development and production began on the more advanced models of Global Hawk. First, in 2003, the Lot 3 LRIP contract added the first Block 20 aircraft, which necessitated production of the larger RQ-4B aircraft and added the EISS. The first of these was delivered on August 21, 2006. Lot 4, which included the first Block 30 aircraft, began in 2005. These events are illustrated in Figure 2. Also in 2005, the overall

Global Hawk buy was increased from 51 to 54 aircraft. Then, in 2009, the Air Force again increased its purchase order for Global Hawk from 54 to 77 aircraft.

3. Global Hawk Program Challenges

Several recurring problems have adversely affected Global Hawk's development. First, there have been intermittent concerns about Global Hawk's reliability, starting from the early days of the program. For example, from 1999 to 2001, RQ-4A aircraft crashed on three separate occasions. The Block 10 experienced several failures in communication systems and reports from the Air Force Operational Test and Evaluation Center (AFOTEC) and the Director, Operational Test & Evaluation (DOT&E) in 2007 cited the low reliability of the Block 10 system. Additionally, operational testing of ASIP and MP-RTIP in 2008 and 2009 showed some deficiencies and developmental challenges. Finally, in 2009 a Block 20 aircraft experienced a serious spoiler actuator and software malfunction that led to a crash landing. All Block 20 and 30 flight test operations were subsequently suspended until successfully completing safety inspection and airworthiness tests in October 2009. Overall, DOT&E found in 2009 that air vehicle reliability is the most significant operational deficiency for all blocks and payloads when Global Hawk is assigned high endurance (28+ hours) missions, a highly desired capability for the aircraft.

Another problem that has affected the Global Hawk program timeline has been its history of significant schedule slips. The 2004, 2005, 2006, and 2009 Selected Acquisition Reports (SARs) all reported breaches from the Acquisition Program Baseline (APB) schedule. Frequent causes cited include delays in software and sensor delivery, falling behind schedule on testing, and bottlenecks resulting from the requirements of concurrent development, testing, and fielding of multiple configurations. In particular, there have been several delays in development testing and evaluation, sometimes by as much as 18 months (Block 20 Initial Operational Test & Evaluation (IOT&E) testing schedule and Block 30 ASIP/EISS testing in 2009, for example). Furthermore, Defense Contract Management Agency (DCMA) Integrated Master Schedule (IMS) audits from December 2008 to January 2010 found a high percentage of missed task deadlines and a tendency for delays in individual tasks to cause unexpected and often serious delays in other parts of the program. Finally, a decision review on Full Rate Production (FRP), originally slated for December 2006/January 2007, has been repeatedly deferred, with the current schedule calling for an FRP decision in April 2011. IOT&E for Block 20 has slipped by more than four years from its original June 2006 target; other increments have been similarly delayed.

Finally, cost growth has been a significant issue for Global Hawk since 2004. Significant Nunn-McCurdy breaches were reported in 2004 for APUC and in 2005 for both APUC and Program Acquisition Unit Cost (PAUC). By the 2006 SAR these grew into critical Nunn-McCurdy breaches (44.87 percent for PAUC and 56.54 percent for APUC). Subsequently, in 2007, a new APB was developed and approved.

4. The 2007 Acquisition Program Baseline

a. Baseline Program Content

The original Global Hawk program was envisioned as a spiral development effort, in which aircraft and payloads would be developed and modified over time. Payloads of interest (including some developed outside the Global Hawk program) would be integrated onto the Global Hawk platform as they became sufficiently mature. However, as a result of cost growth and schedule slip in the program, the 2007 APB restructured the program. This "rebaselined" program had fixed content defined by a set of validated and approved reference documents:

- **Capability Development Document (CDD) –** approved and validated by the Joint Requirements Oversight Committee (JROC) in July 2006. This requirements document supersedes the original 2001 Operational Requirements Document (ORD) and earlier version of the CDD.
- **Cost Analysis Requirements Description (CARD) –** prepared by the Aeronautical Systems Center, Reconnaissance Systems Wing, Global Hawk Systems Group at Wright-Patterson AFB. The current version of the CARD was submitted in March 2006, and approved by the Air Force Program Executive Officer for Aircraft (AFPEO/AC).
- **Test and Evaluation Master Plan (TEMP) –** Revision B, initially submitted October 2006, finalized in September 2007 by the Assistant Secretary of the Air Force (Acquisition); the Director, Operational Test and Evaluation; and the Deputy Secretary of Defense (C^3ISR & IT Acquisition).
- **Acquisition Program Baseline (APB)** agreement document **–** dated 27 March 2007.
- **Acquisition Strategy Report (ASR) –** Change 3, dated 15 June 2007 and signed by the Defense Acquisition Executive (DAE) on 3 July 2007.

The CDD for Global Hawk, together with its appendices, describes the Key Performance Parameters (KPPs) and Key System Attributes (KSAs) of each of the Global Hawk blocks under development. The overarching requirement categories are:

- Key Performance Parameters
  - Endurance
  - Worldwide Operations

  - Dynamic Control
  - Net-Ready (Interfaces and Interoperability)
  - Battlespace Awareness (Sensor Collection Performance)
- Key System Attributes
  - Ground Operations
  - Data Recorder
  - Mission Planning
  - Mission Launch and Recovery
  - Effective Time on Station
  - Electromagnetic Compatibility / Interference
  - Payload Performance
  - Locate
  - Multiple Aircraft Control

Unusually, the specific requirements within these categories are assigned effective dates, so that the required capabilities and specifications for the blocks become more stringent over time. Specific performance threshold and objectives related to each of the KPP areas are presented in the appendices to the CDD.

The CARD for Global Hawk provides a detailed functional description of the subsystems of the Global Hawk UAS, including air vehicles, payloads, ground segment, software, and support. The intent of the CARD is to provide a description of these subsystems that is sufficiently detailed to identify those elements of cost that can be independently estimated. The 2006 CARD describes Blocks 10–40 and the associated ground segment, software, and support elements. It also discusses the security and CONOPS issues relevant to system definition and performance.

The TEMP for Global Hawk describes the test plans for operational evaluation of the blocks, and the criteria by which the blocks will be evaluated. This is somewhat more complicated than a typical TEMP by the time-dependent specifications of the programs, which imply different requirements and different criteria for success at different points in time.

The APB document provides a proposed schedule and cost estimate for the rebaselined program.

The ASR provides a detailed description of the proposed mechanisms for developing and fielding the systems described by the CDD and CARD. The ASR includes a summary of changes from the previous APB acquisition strategy, a description of mission requirements, the contracting approach(es) to be used, the support concept, and the risk management strategy. The ASR confirms the spiral nature of the development approach, the fixed content of Blocks 10–40, and the fact that the dated capability specifications in the CDD define that content.

b. Program Schedule

Table 1 shows both the previous APB schedule and the new APB schedule, as stated in the APB document. Key features of the new schedule included:

- Block 20/30 combined IOT&E completed by November 2009
- Block 40 IOT&E completed by February 2011
- 3 to 4 months allotted for block IOT&E events

Table 1. Acquisition Program Baseline Schedule

Global Hawk						
Milestones	**APB Chg 2 (Development) 12/24/2002 Category/Objective/Threshold**			**APB Chg 3 (Development) 03/23/2007 Category/Objective/Threshold**		
Block 5: Approved for EMD/ LRIP		MAR 2001	MAR 2001	MS II	MAR 2001	MAR 2001
Delivery of first AV with initial Spiral 1 capability	First Asset Delivery	SEP 2003	MAR 2004	First Asset Delivery	SEP 2003	MAR 2004
Increment Zero: Delivery of first AV with initial Spiral 1 capability		SEP 2003	MAR 2004		SEP 2003	MAR 2004
Operational Assessment						
Start		AUG 2004	FEB 2005		**AUG 2005***	**SEP 2005***
Complete		SEP 2004	MAR 2005		**DEC 2006***	**MAR 2007***
Complete Delivery of Blk 10 aircraft		N/A	N/A		**AUG 2006***	**OCT 2006***
Delivery of first Blk 20 aircraft		N/A	N/A		**JAN 2007***	**OCT 2007***
IOT&E Blk 20/30		N/A	N/A			
Start		N/A	N/A		**NOV 2008***	**AUG 2009***
Complete		N/A	N/A		**FEB 2009***	**NOV 2009***
Full Rate Production (FRP) Decision Review (DR)	MS C	NOV 2006	MAY 2007	MS C	**APR 2009***	**JAN 2010***
Deliver first ASIP ready Blk 30 aircraft		N/A	N/A	First Asset Delivery	**MAR 2008***	**DEC 2008***
Deliver first MP-RTIP Blk 40 aircraft		SEP 2009	MAR 2010		**JUL 2010***	**APR 2011***
Blk 40 IOT&E		N/A	N/A			
Start		N/A	N/A		**FEB 2010***	**NOV 2010***
Stop		N/A	N/A	IOT&E	**MAY 2010***	**FEB 2011***
Deliver first ASIP in-line (production) Blk 30 aircraft		N/A	N/A		**MAR 2011***	**DEC 2011***

*Denotes change in Objective/Threshold from prior APB.

Source: Acquisition Program Baseline (APB): Global Hawk (RQ-4A/B), Defense Acquisition Management Information Retrieval (DAMIR), Approval Date: March 23, 2007.

c. Cost Estimates

Table 2 shows both the previous APB cost estimate and the new APB cost estimate, as stated in the March 23, 2007 APB document. Key features of the new cost estimate included:

- Quantity increased from 51 aircraft to 54 aircraft
- APUC estimate increased from ~$57 million to ~$91 million (objective)
- No separate quantities or baseline estimates for the defined blocks

Directive DoDI 5000.2 stated at the time of the APB:

> C1.4.3. APB Content. APB parameter values shall represent the program as it is expected to be produced or deployed. In the case of delivering systems under an evolutionary acquisition strategy, the APB shall include parameters for the next block and, if known, for follow-on blocks. […] ***The APB for a program using an evolutionary acquisition strategy shall contain separate entries for each block.***
>
> […]
>
> C7.15.4.2.1. The SAR shall report the status of total program cost, schedule, and performance; as well as program unit cost and unit cost breach information. […] ***Each SAR shall include a full, life-cycle cost analysis for the reporting program, each of its evolutionary blocks,*** as available, and for its antecedent program, if applicable. (Emphasis added)

Table 2. Acquisition Program Baseline Cost Estimate

Global Hawk				
	APB Chg 2 (Development) 12/24/2002 Objective/Threshold		APB Chg 3 (Development) 03/23/2007 Objective/Threshold	
Then-Year $M				
RDT&E	2392.4	N/A	**3572.0***	N/A
Procurement	3349.3	N/A	**6022.6***	N/A
MILCON	146.7	N/A	**139.8***	N/A
Acq O&M	0.0	N/A	0.0	N/A
Total Acquisition Cost	5888.4	N/A	**9734.4***	N/A
O&S	N/A	N/A	N/A	N/A
Total Life Cycle Cost	N/A	N/A	N/A	N/A
Prog Acq Unit Cost ($M)	115.459	N/A	**180.267***	N/A
Avg Proc Unit Cost ($M)	65.673	N/A	**111.530***	N/A
Base-Year $M (BY 2000)				
RDT&E	2167.1	2383.8	**3076.8***	**3384.5***
Procurement	2904.6	3195.1	**4904.9***	**5395.4***
MILCON	125.0	137.5	**121.9***	**134.1***
Acq O&M	0.0	N/A	0.0	N/A
Total Acquisition Cost	5196.7	N/A	**8103.6***	N/A
O&S	N/A	N/A	N/A	N/A
Total Life Cycle Cost	N/A	N/A	N/A	N/A
Prog Acq Unit Cost ($M)	101.896	112.165	**150.067***	**165.074***
Avg Proc Unit Cost ($M)	56.953	62.648	**90.831***	**99.915***
Quantity				
RDT&E	0	N/A	0	N/A
Procurement	51	N/A	**54***	N/A

*** Denotes change in Objective/Threshold from prior APB.**

Source: Acquisition Program Baseline (APB): Global Hawk (RQ-4A/B), Defense Acquisition Management Information Retrieval (DAMIR), Approval Date: March 23, 2007.

The Global Hawk APB did not conform to this directive, although the Acquisition Strategy Report described the acquisition approach as "spiral development," unchanged from the 2002 APB, with "spirals 1–4 [i.e., Blocks 10/20/30/40] approved." In particular, the program did not report separate cost and quantity estimates for the various blocks in the APB or the subsequent SARs.

C. Projected Unit Cost Growth

1. December 2009 Selected Acquisition Report

The Global Hawk program was rebaselined in 2007, and was required to budget to the CAPE-CA Independent Cost Estimate developed in May of that year. The first full program cost report following the rebaseline was the December 2007 SAR, which agreed almost exactly with the APB cost estimate. For purposes of this report, we will treat the 2007 SAR cost estimates as the baseline estimate against which cost growth will be measured.

No SARs were submitted in 2008. The next official report of program cost and schedule status to the Congress was the December 2009 SAR. The most significant program change in the 2009 SAR was an increase in total procurement quantity from 54 aircraft to 77 aircraft. In spite of the increased quantity, the 2009 SAR reported an 11 percent growth in APUC, which is calculated as total procurement cost (in constant dollars) divided by the number of units to be procured. This was a breach of the APUC baseline given in the APB, although not yet sufficient to trigger a Nunn-McCurdy breach.

The cost variance report provided by the Global Hawk program office in the 2009 SAR identified the sources of procurement cost growth shown in Table 3.

Table 3. December 2009 SAR Cost Variances

Procurement	$M	
Current Change Explanations	**Base Year**	**Then Year**
Revised escalation indices. (Economic)	N/A	-77.7
Increase due to buying three aircraft later than originally planned. Planned aircraft buys in FY 2010, FY 2011 and FY 2015 were each reduced by one aircraft and the three aircraft were rescheduled to be bought in FY 2018 (Air Force) (Schedule)	0.0	+10.7
Total Quantity variance resulting from an increase of 23 aircraft from 54 to 77 (Air Force). (Subtotal)	+1728.9	+2378.8
Quantity variance resulting from an increase of 23 aircraft from 54 to 77 (Air Force). (Quantity)	(+1107.1)	(+1522.8)
Allocation to Estimating resulting from Quantity change. (Estimating) (QR)	(+321.1)	(+442.1)
Allocation to Engineering resulting from Quantity change. (Engineering) (QR)	(+611.6)	(+841.9)
Allocation to Schedule resulting from Quantity change (Schedule) (QR)	(-310.9)	(-428.0)
Increase associated with changed technical definitions for Family of Airborne Terminals, Joint Tactical Radio System, and Ground Segment Re-architecture (Engineering)	+177.2	+246.2
Adjustment for current and prior escalation. (Support)	+4.0	+5.0
Increase in Other Support (Air Force) driven primarily by the addition of calibration support for the Advanced Signals Intelligence Payload and added peculiar support equipment due to increase in planned Combat Air Patrols from 6 to 9. (Support)	+27.0	+41.0
Increase in Initial Spares (Air Force) driven primarily by increase in planned Combat Air Patrols (from 6 to 9) (Support)	+411.5	+517.2
Adjustment for current and prior escalation. (Estimating)	+14.0	+17.2
Increase due to refinement of program estimates for Radar Technology Insertion Program, Airborne Signal Intelligence Payload, and increased risk funds to improve program confidence interval (Estimating)	+448.8	+582.7
Correction to align support and flyaway. (Subtotal)	0.0	0.0
(Estimating)	(-0.3)	(-0.2)
(Support)	(+0.3)	(+0.2)
Procurement Subtotal	+2811.4	+3721.1

Source: Selected Acquisition Report (SAR): Global Hawk (RQ-4A/B), Defense Acquisition Management Information Retrieval (DAMIR), December 31, 2009.

Base Year amounts are FY 2000 millions of dollars. For the remainder of this report, all dollar costs are in constant FY 2000 dollars unless otherwise noted.

These costs can be categorized as follows:

- The cost to buy 23 additional aircraft (all from the more expensive Block 30 and 40 configurations)
- Upward revision of procurement cost estimates for the MP-RTIP and ASIP payloads
- The cost of procuring more spares than originally planned (50 percent due to additional ASIP and MP-RTIP sensor spares)
- Additional costs for technical requirements associated with:
  - Joint Tactical Radio System (JTRS) integration
  - Family of Advanced Beyond-Line-of-Sight Terminals (FAB-T) integration
  - Ground Station Rearchitecture (defined in section entitled "Ground Station Rearchitecture")

- Additional support costs related to new ASIP calibration facilities
- Adjustments to previous assumptions about inflation rates

The cost growth described in the 2009 SAR corresponds to an 11 percent increase in APUC. PAUC was predicted to decline by 4 percent, due primarily to the increased procurement quantity. This forecast cost growth would not have been sufficient, by itself, to warrant a PARCA root cause analysis.

All cost comparisons and assessments in this evaluation are based on documents provided by the Global Hawk program office, Northrop Grumman, and CAPE-CA. Where costs were not well defined or categorized, we have made the best estimates we could from the available data.

2. CAPE-CA Additional Projected Cost Growth

In the spring of 2010, CAPE-CA was asked to develop a rough estimate of Global Hawk cost growth. This estimate was presented at the 25 May 2010 Global Hawk Overarching Integrated Product Team (OIPT) meeting. It projected 23 percent APUC growth relative to the 2007 APB, approaching the 25 percent threshold that would trigger a Nunn-McCurdy breach and subsequent program review. In response to this estimate, Mr. Frank Kendall, the Principal Deputy Under Secretary for Acquisition, Technology and Logistics, initiated a “Nunn-McCurdy-like” review of the Global Hawk program, including a PARCA root cause analysis of the cost growth predicted by CAPE-CA.

The CAPE-CA estimated growth areas were:

- Aircraft mix changes (i.e., a higher proportion from the more expensive aircraft blocks)
- Spares and Peculiar Support Equipment (PSE)
- Communications Rearchitecture
- Ground Station Rearchitecture
- Palmdale production acceptance testing (PAT) and modification facility
- Engineering Change Orders (ECO) and Diminishing Manufacturing Sources (DMS)
- Sensor depot standup
- IOT&E test replan

The cost growth amounts associated with these categories are shown in Table 4.

Table 4. CAPE-CA Cost Growth Estimate

Growth Area	CAPE-CA estimated amount (BY 2000$)
Sparing and PSE	$355
Aircraft Mix	$330
Palmdale PAT and mod facility	$190
IOT&E replan	$70
GS rearchitecture	$200
Comms rearchitecture	$115
ECO & DMS	$175
Sensor depot standup	$160

Table 5 shows an attempt to reconcile the SAR and CAPE-CA cost growth estimates, to the extent possible. Note that these figures are total cost growth, not unit cost[3]. Blue-shaded cells in the table indicate areas where we feel there is close correspondence between some subset of SAR variance items and CAPE-CA growth areas. Unshaded cells indicate cost areas cited by one source but not the other.

3 Because the CAPE-CA estimate describes unit cost growth, the marginal total cost of additional aircraft at the same average unit cost was not included explicitly in their list. We have reconstructed that value from the APB and the other CAPE-CA cost growth categories. We discuss the rationale for assuming a constant unit cost later in this section.

Table 5. Side-by-Side Comparison of CAPE-CA and SAR Cost Growth Areas

	SAR Variances	CAPE Estimated Growth	
APB Baseline	**$ 4,904.9**	**$ 4,904.9**	
Additional aircraft	$ 1,107.1		
Revised estimates (RTIP, ASIP) and contingency	$ 448.8		
Eng and schedule effects of increased buy	$ 300.7		
FAB-T, JTRS	$ -		
Subtotal	$ 1,856.6	$ 2,088	Additional aircraft
Aircraft mix effect	$ 321.1	$ 330	Aircraft mix effect
Increased initial spares	$ 411.5	$ 355	Sparing and PSE
Comms Re-architecture	$ -	$ 115	Comms Re-architecture
GS re-architecture	$ 177.2	$ 200	GS re-architecture
ASIP calibration	$ 27.0	$ 190	Palmdale PAT and mod facility
Other adjustments	$ 66.2	$ 175	ECO & DMS
		$ 160	Sensor depot standup
		$ 70	IOT&E replan
Total procurement	**$ 7,764.5**	**$ 8,588.3**	

SM FY 2000
Shaded boxes denote areas of directly comparable program content between the CAPE-CA analysis and the SAR variance reports.

3. A Combined Estimate of Likely APUC Growth

The SAR and CAPE-CA cost growth estimates and categories do not align perfectly. Not only are the assigned dollar quantities somewhat different, but there are areas of cost growth that are not cited by both estimates. In particular, the program office SAR cost variance cites the cost of building and staffing an anechoic chamber facility to support ASIP sensor calibration; the CAPE-CA estimate does not include this facility. Conversely, the CAPE-CA estimate cites costs associated with new facilities for PAT and sensor depot support, which are not included in the SAR variance estimates.

Using the cost category alignment in Table 5, IDA developed a combined estimate of program cost growth which reflects a unified compromise estimate of the changes in estimated cost since the 2007 APB. That combined estimate is shown in Table 6.

Table 6. Combined APUC Growth Estimate

Procurement Cost Area	Growth ($M)	Proximate Cause
Additional aircraft	$1,400	Increased procurement quantity
Aircraft mix	$330	
Sensor unit cost	$450	Upward revision of cost estimate
Spares	$355	
Engineering Change Orders	$100	
Other recurring flyaway costs	$240	
Communications rearchitecture	$115	Recognition of missing CDD content
Ground Station rearchitecture	$200	
Sensor depot	$160	
Palmdale PAT & mod facility	$190	Inadequate test resources
Diminishing Mfg Sources	$75	
"IOT&E Replan"	$70	
ASIP calibration facility	$30	
Estimated procurement growth since 2007	$3,715	
Estimated Total Procurement	$8,620*	

*CAPE-CA figure of $8,588.3 does not include ASIP calibration facility.

The analysis in this report assumes that these are the cost growth categories and amounts to be explained by the root cause analysis. Where both the program office and CAPE-CA identified an area of cost growth, but disagreed on the amount, we have used the CAPE-CA numbers, since our task was to explain the increased costs identified by CAPE-CA. The following paragraphs define and describe these cost growth areas in turn.

a. Additional Aircraft and Aircraft Mix

Typically, an increase in procurement quantity leads to a reduction in APUC, due to learning curve effects and the amortization of nonrecurring costs over a larger number of units. In the case of Global Hawk, this is not the case. The program anticipates very little nonrecurring cost—only 0.4 percent of flyaway costs—so the dilution of those costs over 77 instead of 54 aircraft makes little difference in overall unit cost. Non-flyaway costs, such as support and initial spares, scale with quantity, and so do not affect unit cost. At the same time, the Global Hawk program has shown no evidence of cost progress ("learning") to date, and the program office is not projecting significant learning for future units. Given this, it was not unreasonable for the CAPE-CA cost growth estimate to implicitly assume that the marginal unit cost of additional aircraft would be about the same as the average cost used in the APB estimate, prior to adjusting for configuration differences among blocks and itemized areas of cost growth. The additional costs of buying the marginal aircraft from the more expensive blocks are accounted for separately as “aircraft mix.”

The 2009 SAR quantity adds 23 aircraft to the baseline quantity of 54, for a total of 77 aircraft. According to the cost model at the time of the 2007 APB, 23 new aircraft would have cost ~$1.4 billion, assuming that the mix of block variants remained unchanged. However, the 23 new planned aircraft comprise 16 additional Block 30 with ASIP (for a total of 41) and 7 additional Block 40 (for a total of 21). These blocks are estimated to be significantly more expensive per unit than Block 10 or Block 20 aircraft;[4] thus, increasing their proportion of the total buy results in increased average unit cost even in the absence of Block 30 or Block 40 unit cost growth.

As explained above, no increased learning or spreading of nonrecurring costs as a result of the increased buy is reflected in the CAPE-CA estimate. Because of this, the $1.4 billion that would have been paid to increase the quantity without changing the block mix does not figure in CAPE-CA’s account of APUC growth. Both the SAR cost variance (relative to the baseline) and CAPE-CA APUC growth estimate associated with the additional aircraft itemized the effect due solely to the fact that the additional aircraft are to be more expensive than the APB average aircraft. This itemized cost is listed in the combined estimate (Table 6) as “Aircraft Mix,” and is estimated by CAPE-CA at $330 million.

b. Sensor Unit Cost and other Recurring Flyaway Costs

Both CAPE-CA and the 2009 SAR variance report attribute significant cost growth to upward revision of the APB baseline estimate in certain areas. The SAR explicitly attributes ~$450 million in procurement cost growth to increased estimates of the costs of the MP-RTIP and ASIP sensor payloads. It also asserts $411.5 million in increased procurement of spares.

The CAPE-CA estimate requires more careful interpretation. CAPE-CA estimated ~$8.6 billion as the total procurement cost of the 77 aircraft to be procured. This estimate was based on aircraft and payload estimates developed from historical cost estimating relationships and actual prototype hardware costs to date for Global Hawk, MP-RTIP, and ASIP. Subtracting the itemized cost growth elements cited by CAPE-CA in Table 4 leaves ~$7 billion in total procurement, which is $2.1 billion above the APB procurement

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4 It is difficult to estimate precise unit costs by block, because the Global Hawk program does not track either costs or quantities by block. Block 30, in particular, is difficult to estimate because some (but not all) of the sensors are being procured as retrofits using “modification of aircraft” funds. Overall, based on program office figures, we estimate that the unit cost of a Block 10 aircraft was roughly $50 million (BY 2000), the projected unit cost as of December 2009 for a Block 20 was roughly $85 million, for a Block 30 was roughly $120 million, and for a Block 40 was roughly $100 million. These estimates include ground segment and other program-wide costs amortized across all 77 planned units.

cost estimate. As noted above, ~$1.4 billion of that is the cost of 23 additional aircraft at the original unit cost. The remaining ~$690 million represents an upward revision to the APB cost estimate that was not itemized by CAPE-CA. In the combined estimate, we attribute ~$450 million of this to MP-RTIP and ASIP cost growth, as itemized by the program office in the SAR variances, and the remaining ~$240 million to upward revision of other (unspecified) recurring flyaway cost estimates.

c. Spares

Both the December 2009 SAR and the CAPE-CA growth estimate listed increased cost of spares as a major growth area. The SAR variance stated $411.5 million in additional procurement of spares, and attributed this growth to an increase in the proposed number of Global Hawk Combat Air Patrols (CAPs) from six to nine.

CAPE-CA estimated $355 million for increased spares. This estimate was not based on the projected number of CAPs, but was derived from a historical cost estimating relationship (CER). In keeping with our tasking to explain the CAPE-CA numbers, we used $355 million as the predicted growth due to spares in the combined estimate. This may understate the likely growth in spares procurement, given the increased operating tempo (OPTEMPO) and recent growth in sensor cost estimates. Sensor spares account for roughly 50 percent of total spares costs.

d. Engineering Change Orders (ECOs)

The Global Hawk Program Office Estimate at the time of the 2007 rebaseline predicted the total cost due to ECOs using Northrop Grumman's historical ratio of ECO costs to procurement cost for aircraft procurement. Actual data to date in the Global Hawk program show a higher rate of ECO costs than the historical average. As a result, CAPE-CA identified this as an area of APUC growth, estimated at ~$100 million.

e. Communications Rearchitecture

Several aspects of Global Hawk's communications systems need to be rebuilt and/or redesigned to account for DMS, unmet CDD requirements not included in previous cost estimates, and, in some cases, new program content. The Global Hawk program refers to this activity as "Communications Rearchitecture." DMS issues are plaguing legacy communications equipment, creating the need for redesigns to make newer communications equipment backwards-compatible with out-of-date legacy equipment used in Global Hawk. Additionally, 25 requirements identified in the 2006 CDD cannot be met using the current communications architecture. Examples include Multi-day Encryption, Broadband INMARSAT, IP-based CDL, Ka SATCOM (200+ Mbps), Three Voice Network, IPv6 compatibility, Jam-resistant Voice (Have Quick II), and Independent/Simultaneous Data Flows. Incorporation of these capabilities has been made more difficult given that many rely on newer technologies that are not interoperable with some of Global Hawk's obsolescent equipment. Additionally, the USAF has now prioritized implementation of the dual-band SATCOM (Ku/Ka) CDD requirement for Blocks 30 and 40, and incorporating the FAB-T.

Communications Rearchitecture also includes the costs of meeting some new externally-driven requirements. For example, a National Security Agency (NSA)-directed cryptographic modernization mandate requires that the Global Hawk communications systems be redesigned to accommodate new cryptographic devices. The cost of complying with this directive is included in the estimated costs of Communications Rearchitecture.

CAPE-CA estimates $115 million in additional procurement costs are needed for those modernizations and upgrades identified by the program office in their current Communications Rearchitecture plan. It is difficult to distinguish which of the capabilities and performance requirements being addressed by that plan were assumed by the 2007 APB estimate. It is clear that the baseline estimate did not include the costs to provide all of the modernized communications and interoperability requirements specified (with delivery dates) in the CDD. It is also clear that the current Communications Rearchitecture plan does not address all of the remaining unfunded CDD requirements.

f. Ground Station Rearchitecture

The Global Hawk program is also planning a major redesign of the ground stations from which UAS missions are planned and controlled. This "Ground Station Rearchitecture" will have two elements: modernization of many hardware and software elements of the ground station, and a transition from a portable shelter-based ground station to permanent installations in fixed-site buildings.

The modernization portion of Ground Station Rearchitecture includes necessary hardware upgrades in elements such as antennas, Ultra High Frequency (UHF) SATCOM, and Common Data Link (CDL) to meet 2006 CDD requirements. As with the Communications Rearchitecture, it also addresses issues of DMS and technology obsolescence.

The wholesale replacement of large portions of the hardware and software in the Ground Station provides an opportunity for the program to transition from the current installation in standard portable shelters to a set of permanent installations in buildings. It is not clear when the intent to shift to permanent ground installations was first included in program content, but it does not seem to be part of the 2006 CDD specification. For that reason, we classify the transition to permanent buildings as added program content, and not cost growth relative to existing requirements.

CAPE-CA estimates $200 million in additional procurement costs for hardware and facilities. These costs are not reflected in the December 2009 SAR. Software elements of the Ground Station Rearchitecture will be funded through RDT&E, and are explicitly included in the December 2009 SAR RDT&E cost estimate.

g. Sensor Depot

Originally, the Global Hawk program office had planned to share sensor depot costs with other sensor development programs and ISR platform programs. These platforms are no longer expected to carry these sensors, so the Global Hawk program will bear the full support burden. CAPE-CA estimates these newly-recognized depot costs at $160 million.

h. Palmdale PAT and Modification Facility

The original test schedule for Blocks 20/30/40 was extremely ambitious. Developmental testing (DT) and operational testing (OT) were combined, to minimize the demand on test resources. Test events were “pipelined” to allow concurrent DT, OT, and PAT of different blocks as they were developed and built. When testing revealed necessary redesign and rework, the test schedule provided no flexibility to recover, and major schedule slips were incurred. The carefully interleaved sequence of tests became an unexecutable stack of concurrent tests, with the various Global Hawk blocks competing among themselves for range time, flight hours, and test personnel. When disruptions such as these to the schedule occurred, the ability to combine tests for multiple purposes and stagger test times without incurring development delays was lost. In particular, PAT for Block 20 began to compete sharply with essential DT and OT activities for Blocks 30 and 40, as well as test activities associated with the EuroHawk FMS variant.

To mitigate this resource conflict, the program decided to build and staff a new PAT facility at Northrop Grumman’s Palmdale facility. When this new facility is up and running, it will allow PAT activities for earlier blocks to run concurrently with DT and OT test activities for later blocks and EuroHawk. CAPE-CA estimates $190 million will be required to implement this new PAT capability.

i. Diminishing Manufacturing Sources (DMS)

DMS is a blanket term for the various costs associated with component hardware and software that is less available, less well-maintained, or more expensive than it was when originally included as part of the system design. In extreme cases, modifications or spares are simply unobtainable for legacy components.

In addition to unplanned facilities costs, overall program delay led to increased DMS-related procurement costs. Obsolescence of certain electronic and software components meant that some DMS mitigation activities, originally planned for the

Operations and Support (O&S) phase of the program, had to be paid for with Procurement funds. The stretching of the test-fix-test cycle for Block 30 and Block 40 LRIP led to a higher proportion of systems engineering and program management (SE/PM) costs than had been planned, increasing APUC even further.

Common manifestations of DMS include discontinued product lines, discontinued product support, suppliers going out of business or merging with their competitors, technology obsolescence, and insuperable reliability issues. In general, commercial off-the-shelf (COTS) components are more subject to DMS than custom components, due to the shorter product life-cycles and profit-driven technology choices of the commercial sector. Commercial software is particularly prone to DMS issues.

As noted above with regard to Communications Rearchitecture and Ground Station Rearchitecture, DMS has been a major concern in the Global Hawk program. The original ACTD program was encouraged to make maximum use of commercial components and software, in order to minimize the costs of fielding an initial capability. As a result, roughly 80 percent (by count) of Global Hawk parts were COTS.[5] However, the additional development requirements of Block 30 and Block 40, combined with the many schedule delays of the program, have extended the required service life of the aircraft and systems. As a result, many of the components used in the initial design are now difficult or impossible to maintain, or at risk of becoming so. Others do not support Block 30 and 40 performance requirements. CAPE-CA estimates ~$75 million in unplanned procurement costs, beyond those already ascribed to Communications Rearchitecture and Ground Station Rearchitecture, for DMS mitigation.

j. "IOT&E Replan"

As described above, the Global Hawk program has been unable to conduct all planned test activities in parallel at Edwards AFB. The new PAT facility at Palmdale will help to alleviate the resource crunch, but that facility will not be available immediately. As an interim measure, the program is standing up a temporary PAT capability at Beale Air Force Base in northern California. The procurement costs associated with this action are not included in the December 2009 SAR variance report. CAPE-CA estimates an additional procurement cost of $70 million for facilities, instrumentation, staffing, etc. to implement this temporary capability.

k. ASIP Calibration Facility

Integration of the ASIP sensor on the Block 30 aircraft requires the use of a specially-instrumented anechoic chamber in which the sensor's response to carefully

[5] G. Guerra, "Global Hawk Review – OSD PARCA Team," OSD-PARCA Presentation, July 2010.

calibrated external signals can be measured and adjusted. The Global Hawk program currently has access to only one suitable facility, at Edwards AFB. However, the Global Hawk program must compete with other aircraft programs for access to this facility and its support staff. As a result, ASIP calibration has become a source of schedule slip in the fielding of Block 30.

To alleviate the bottleneck, the contractor is planning to build a second suitable anechoic chamber facility at a contractor site. The program office estimated $27 million in additional procurement costs is required for this facility. CAPE-CA did not include an estimate for this facility in their May cost growth estimate, but after discussions with CAPE-CA personnel, we have assigned a rough estimate of $30 million in the combined estimate.

D. Quantifiable Areas of Unit Cost Growth

The procurement cost growth quantified in the combined estimate falls into four primary areas. These areas are:

- Changes in aircraft mix, resulting in procurement of a higher proportion of Block 30/40 aircraft
- Upward revision of APB cost estimates for sensor payloads, initial spares, and many “below the line” cost elements
- Belated recognition of baseline program content that was missing from the APB estimate
- Costs incurred to mitigate a lack of adequate test resources

The assignment of cost growth to these areas, with the relative contributions to APUC growth, is shown in Figure 3. We discuss the rationales behind these identified factors in turn in the following sections. As explained on page 17, the $1.4 billion estimated cost for 23 additional aircraft (prior to accounting for changes in configuration mix) was not projected by CAPE-CA to affect APUC, and therefore does not appear in Figure 3.

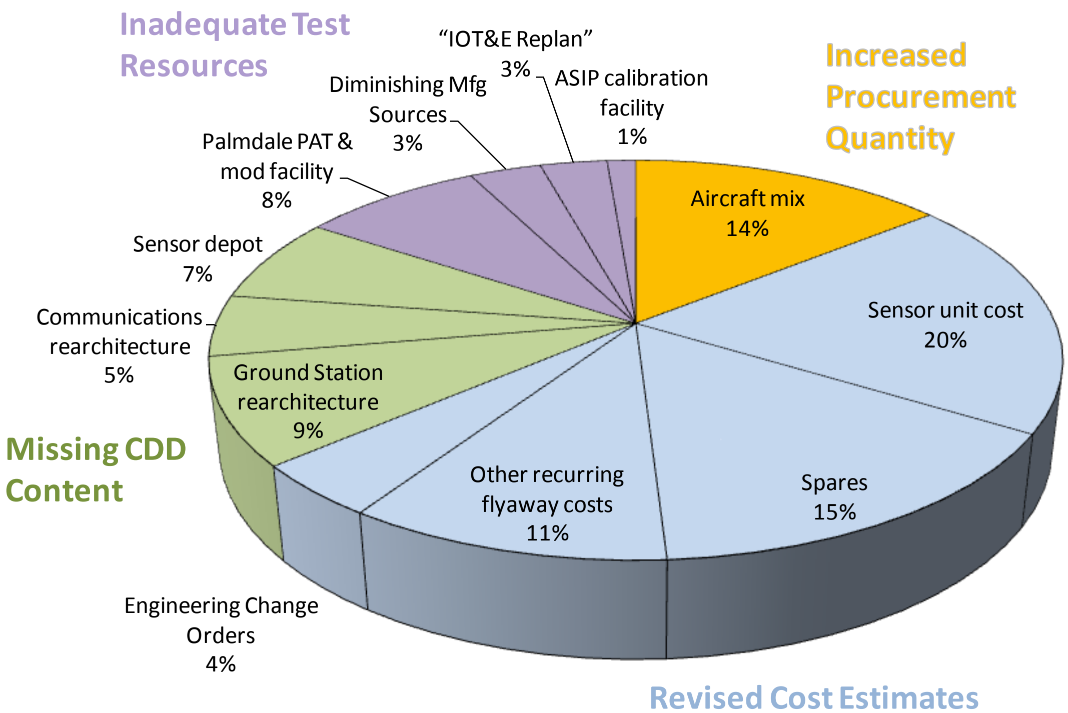

Figure 3. Relative Contributions of APUC Growth Areas

1. Procurement of Additional Aircraft

As noted above, adding to the procurement quantity usually decreases APUC rather than increasing it. For the Global Hawk program, the increase in APUC driven by the additional buy was caused by the higher average cost of Block 30 and Block 40 aircraft (now 83 percent of planned units), compared to the average cost of the 54 Block 10/20/30/40 aircraft in the baseline buy. CAPE-CA and the program office agree that this accounts for ~$330 million in procurement cost growth, or about 14 percent of the APUC growth. This amount does not reflect any increase in the predicted cost of Block 30 or Block 40 aircraft; it is simply an arithmetic consequence of a new requirement for more Block 30 and Block 40 aircraft than were originally desired. There was no offsetting decrease in APUC from this increase in quantity, because Global Hawk shows little or no learning curve effect in airframes or sensors, and there is almost no nonrecurring procurement cost in the program.

2. Upward Revision of Cost Estimates

The combined estimate identifies several areas that were included in the 2007 APB estimate, but that are now expected to cost more than was planned.

The primary area of estimate growth in the 2009 SAR variance report is the cost of the ASIP and MP-RTIP sensors. Both of these sensors were originally developed in

MDAPs external to the Global Hawk program. Furthermore, neither of these external programs included any procurement cost estimates in their SAR filings prior to being merged into the Global Hawk program. Initial contractor estimates of sensor unit costs have proven to be over-optimistic. The SAR variance report estimates total sensor cost growth of ~$450 million relative to the APB estimate. This figure is consistent with CAPE-CA estimates, and we have adopted it in the combined estimate.

The CAPE-CA estimate implies additional (non-itemized) recurring flyaway cost growth of $240 million, or more than $3 million per aircraft. This estimate was derived from an analysis of actual recurring costs to produce the few EMD units built to date. Recent program office estimates suggest that most of this cost growth is in the aircraft systems, which are currently predicted to be ~6 percent more expensive per unit than in the APB estimate.[6]

Finally, both the program office and CAPE-CA have greatly increased their estimates of the cost of initial spares since the 2007 APB. The 2009 SAR cost variance report asserts ~$410 million in additional procurement of spares. It attributes the growth to a planned increase in the number of CAPs from 6 to 9, with a corresponding increase in projected flying hours. CAPE-CA independently estimated $355 million in increased cost of spares, using a CER driven by unit recurring flyaway costs of the system. This CER did not account for a 50 percent increase in the number of CAPs. The combined estimate uses the CAPE-CA figure, in accordance with our task direction. Future cost estimates should account explicitly for the proposed Concept of Operations (CONOPS).

3. Baseline Program Content Missing in the Baseline Estimate

The combined estimate also identifies several areas that were part of the official program requirements at the time of the 2007 rebaseline, as established in the CDD, CARD, and TEMP—but were not included in the APB estimate or the December 2007 SAR estimate. These itemized growth areas are:

- Communications Rearchitecture
- Ground Station Rearchitecture
- Sensor Depot standup

For the most part, each of these areas comprises necessary activities to meet system or program requirements that were known and documented at the time of the APB. We discuss each in turn.

[6] K. Scherer, "OSD0714 - 4 Follow Up 1 and 2," briefed to OSD PARCA team, July 14, 2010.

a. Communications Rearchitecture

Several aspects of Global Hawk's communications systems need to be rebuilt and/or redesigned to account for DMS, unmet CDD requirements that were not included in previous cost estimates; and, in some cases, new program content. The efforts included in the December 2009 Program Office Estimate (POE) briefings are:

- **Joint Tactical Radio System (JTRS) Airborne/Maritime/Fixed (AMF) integration.** Section 6.1.3.2 of the CDD requires that Block 30 aircraft be equipped with AMF-JTRS radios. This requirement has an implementation date of FY 2014. JTRS program delays and size/weight/power issues have added significant risk to this requirement. This is not a KPP or KSA requirement.
- **Family of Advanced Beyond-Line-of-Sight Terminals (FAB-T) integration.** The CDD also requires that Block 30 and Block 40 aircraft be capable of using Wideband Gapfiller Satellite (WGS) Ka-band SATCOM. The planned implementation of this capability is to equip Global Hawk with the FAB-T terminal, currently under development, which will be WGS-capable. FAB-T will also enable a forward command and control (C^2) link data rate of up to 10 megabits per second (Mbps) for management of advanced sensors C^2. This is not a KPP or KSA requirement.
- **Internet Protocol (IP)-based Common Data Link (CDL) / Extended Tether Program (ETP) upgrade.** The ETP system provides capability for secure beyond-line-of-sight C^2 data, payload data, and voice. It also supports selectable data rates for payload data, providing a near-term alternative and long-term backup to the WGS data link, but at lower data rates. The planned upgrade will increase the maximum selectable data rate to 15 Mbps. Two alternative implementations of the upgrade have been identified. The technically easier but less desired option would install an additional 20-pound circuit card rack next to the existing ETP unit. The preferred option would redesign the ETP unit to accept the additional cards. This is not a KPP or KSA requirement.
- **Replace on Station.** In order to meet the threshold Effective Time on Station (ETOS) requirements for the Global Hawk system, it will be necessary to be able to replace a Global Hawk aircraft on station. This requires adding a low-band Ku capability to the Launch and Recovery Element (LRE) to support the necessary second communications and C^2 link. The ETOS requirement, and its implied requirement for simultaneous operations of multiple aircraft on station, is a KSA in the CDD.
- **Controller Pilot Data Link Communications (CPDLC) / Automatic Dependent Surveillance-Addressed (ADS-A).** CPDLC and ADS-A are required to meet Global Air Traffic Management (GATM) requirements:

specifically, Required Navigation Performance Level 4 (RNP-4) Oceanic and Future Air Navigation System (FANS) compliance. This effort also includes Mode 5 Identification Friend or Foe (IFF) Enhanced Surveillance upgrades (for future USAF and NATO interoperability) and multi-day IFF keying in support of Global Hawk high endurance requirements. Worldwide operations in all categories of airspace is a threshold KPP in the CDD. CPDLC and ADS are standards that were known to be part of future air traffic control compliance requirements at the time of the adoption of the 2006 CDD.

- **Multi-day Encryption.** As with the Replace On Station capability and multi-day IFF keying, Multi-day Encryption supports high-endurance operations and ETOS. The planned effort will provide the ability to insert multiple Communications Security (COMSEC) keys into the system, allowing up to three days of operation (with one spare key). To do this, it will be necessary to replace the current COMSEC chips, which have only a single key capability. The KGV-68B and KGV-135 chips must be replaced with KGV-135A chips, additional traces and jumpers to the new chips must be added, and the COMSEC software must be modified to recognize and synchronize the keys. Multi-day Encryption capability is a threshold FY 2012 CDD requirement, but is not a KPP or KSA.
- **Other minor upgrades.** In addition to the significant efforts described above, the Communications Rearchitecture will also address several minor requirements. The program office characterizes these efforts as:
  - RS422 upgrade,
  - ACTM/SA Messaging updates,
  - Point-to-Point Interoperability,
  - IPv6, and
  - Tactical-CDL baseline/demo.

The estimated total then-year cost of these minor upgrades is ~$25 million.

These are not all of the communications-related requirements in the 2006 CDD that remain unmet and unfunded. Other examples include Sense-and-Avoid (a KPP), Broadband INMARSAT, Jam-resistant Voice (Have Quick II), and Independent/ Simultaneous Data Flows.

Communications Rearchitecture also includes the costs of meeting some new externally-driven requirements. For example, an NSA-directed cryptographic modernization mandate requires that the Global Hawk communications systems be redesigned to accommodate new cryptographic devices. The cost of complying with this directive is included in the estimated costs of Communications Rearchitecture.

CAPE-CA estimates $115 million in additional procurement costs will be required for those modernizations and upgrades identified by the program office in their current Communications Rearchitecture plan. A recent POE cites $250 million then-year (budget) dollars for the effort. It was not possible for us to determine which of the capabilities and performance requirements that are being addressed under Communications Rearchitecture were assumed by the 2007 APB estimate. It is clear that the baseline estimate did not include the costs to provide all (or even most) of the modernized communications and interoperability capabilities specified (with dates) in the CDD. It is also clear that the current Communications Rearchitecture plan does not address all of the remaining unfunded CDD requirements.

b. Ground Station Rearchitecture

As with the Communications Rearchitecture, multiple aspects of the Global Hawk Ground Station are suffering DMS or impending obsolescence. The Global Hawk program is now planning a major rearchitecture of the Ground Station from which UAS missions are planned and controlled. This rearchitecture will have two elements: modernization of many hardware and software elements of the ground station, and a transition from a portable shelter-based Ground Station to permanent installations in fixed-site buildings.

The modernization portion of Ground Station Rearchitecture has both software and hardware aspects. The software rearchitecture is being funded primarily through RDT&E, while the hardware is funded from procurement. The hardware portion includes necessary upgrades in the following systems:

- Mission Control Element (MCE)
  - Tactical Field Terminal (TFT) antenna
  - Tactical Interoperable Ground Data Link (TIGDL) antenna upgrade to dual band
  - UHF SATCOM antenna
- Launch and Recovery Element (LRE)
  - Tactical Common Data Link (TCDL) antenna
  - UHF SATCOM and line-of-sight antenna
  - Upgrade to 274 Mbps wideband communications
  - Voice relay via air vehicle
  - Special Category 1 (SCAT-1) Differential Global Positioning System (GPS)
- INMARSAT support for Replace on Station

These modifications appear to all be in support of meeting (or continuing to meet) 2006 CDD requirements.

The replacement of large portions of the hardware and software in the Ground Station provides an opportunity for the program to transition from the current installation in standard portable shelters to a set of permanent installations in buildings. Current planning anticipates that these buildings would be located at Main Operating Bases (MOBs) and/or Forward Operating Bases (FOBs). It is not clear when the intent to shift to permanent ground installations was first included in program content, but it does not seem to be part of the 2006 CDD specification. For that reason, we classify the transition to permanent buildings as added program content, and not cost growth relative to existing requirements.

Software elements of the Ground Station Rearchitecture will be funded through RDT&E, and are explicitly included in the December 2009 SAR RDT&E cost estimate. CAPE-CA estimates $200 million in additional procurement costs will be required for hardware and facilities associated with Ground Station Rearchitecture. These costs are not reflected in the December 2009 SAR. With the exception of the costs of the transition from shelters to fixed installations, Ground Station Rearchitecture costs constitute baseline program content omitted from the APB (and subsequent) estimates.

c. Sensor Depot Standup

Originally, the Global Hawk program office had planned to share sensor depot costs with other sensor development programs and ISR platform programs. For example, it was expected that the MP-RTIP radar would be used by the E-8 Joint STARS and E-10A aircraft, as well as by Global Hawk. The costs of an MP-RTIP depot were to have been shared by the four associated programs. However, the Joint STARS program decided to focus on a larger radar, the E-10A was cancelled, and the MP-RTIP program was folded into the Global Hawk program. In similar fashion, the ASIP sensor was originally also for use on U-2, but the Air Force now plans to retire the U-2 SIGINT capability.

Because these platforms are no longer expected to carry these sensors, the Global Hawk program will bear the full support burden. In a November 2006 briefing to the Defense Acquisition Executive, the program indicated that they would support ASIP and MP-RTIP sensors from a dedicated Global Hawk program depot. However, activation costs for this facility were not included in the baseline program estimate at the time of the APB. Funding was deferred to the FY 2010 POM, and later further deferred; the necessary funds were still not included in the December 2009 SAR. CAPE-CA estimates $160 million in additional nonrecurring procurement cost to implement this function. These costs constitute baseline program content omitted from the APB (and subsequent) estimates.

4. Inadequate Test Resources

Several of the cost growth areas identified in the combined estimate are the direct result of inadequate test resources for the program as defined and executed. These include the costs of the temporary PAT capability at Beale AFB; the new PAT facility at Palmdale, California; and the new anechoic chamber facility for ASIP calibration.

There is an interaction in play here between the available test resources and the planned test schedule at the time of the 2007 rebaseline. Had that schedule been executable, the available test resources might have been adequate. However, the planned schedule was unrealistic—there was essentially no possibility that the sequence of planned test events would be completed without any delays, needs for rework, setbacks due to weather or mishaps, or other disruptions. Once the schedule was disrupted, the simultaneous demand for test resources by the various blocks (and the commercial Global Hawk FMS program) created further delays and disruptions throughout the program, and consequent cost growth. In particular, some of the procurement costs of DMS mitigation were incurred because the program was not able to defer those costs beyond the procurement phase of the program, to be paid for with O&S funds. While this does not affect overall program life cycle costs, it does increase procurement costs as a proportion of life cycle costs, and thus causes an increase in APUC.

CAPE-CA estimates ~$290 million in procurement costs associated directly with standing up additional test resources will be required to relieve some of the testing bottleneck. Indirect costs associated with extended RDT&E are not captured in APUC growth. Indirect costs associated with testing delays, such as increased SE/PM costs and miscellaneous DMS mitigation costs, are captured above in the non-itemized portion of the section entitled "Upward Revision of Cost Estimates."

E. Root Causes of Unit Cost Growth

Having presented the cost growth categories as quantified in the combined estimate, and having identified factors directly contributing to cost growth in those areas, we now examine various root causes underlying these factors.

The Weapon Systems Acquisition Reform Act of 2009 (WSARA) enumerates seven specific root causes to be identified, where applicable, in a PARCA root cause analysis. These are shown in Table 7.

Table 7. WSARA Root Causes

The WSARA Taxonomy of Root Causes	
1. Unrealistic performance expectations	5. Changes in procurement quantities
2. Unrealistic baseline estimates for cost or schedule	6. Inadequate program funding or funding instability
3. Immature technologies or excessive manufacturing or integration risk	7. Poor performance by government or contractor personnel responsible for program management
4. Unanticipated design, engineering, manufacturing, or technology integration issues arising during program performance	8. Any other matters

We have identified five of these seven root causes as specific causes of the cost growth identified in the combined estimate. We present them in order of decreasing importance to overall APUC growth for the Global Hawk program, and discuss the specific actions and events that led to that growth.

1. Poor Performance by the Government and by Contractors

The most important WSARA root cause category in the Global Hawk program has been "poor performance by the government and by contractors." Many of the cost growth areas identified in this report are traceable, at least in part, to poor performance by the government (at all levels) and the contractors. We note in particular the following, enumerated separately for "government" and "contractors."

a. Government

1) Oversight of the Program Rebaseline

The original transition of the Global Hawk program from ACTD to MDAP envisioned a spiral development approach in which sensors would be integrated onto aircraft over time as technology matured. The philosophy was to be "when it is ready, it will fly." This led to a program with poorly defined requirements and priorities. At the same time, external demand for specific capabilities (on an externally defined schedule) created a situation in which development was no longer spiral, but instead consisted of concurrent development of multiple aircraft variants. The inability of the program acquisition approach to cope with these demands contributed to the first Nunn-McCurdy breach in 2006.

The rebaseline in 2007 provided an opportunity for OSD and the Air Force to restructure the program to reflect the new reality of what was being required. The spiral approach was no longer relevant to Blocks 10–40, and any additional increments beyond those blocks were sufficiently vague and low priority as to be outside the scope of a program trying to recover from major cost and schedule breaches. DoDI 5000.2 required that separate acquisition baselines be established for the four blocks, including separate quantity, cost, and schedule baselines (and corresponding separate reporting and tracking).

Instead, OSD and the Air Force encouraged the program to continue as a (nominally) spiral development. The program was managed as an aircraft program with occasional payload integration activities, rather than as the three or four simultaneous fully-specified ISR system development efforts it had become. Division of program management responsibilities between airframe program and sensor programs contributed to this confusion. Separate baselines for the four blocks were not established or tracked. The program was slow to react to the resource requirements of concurrent development, in part because the APB and Acquisition Strategy did not make that concurrency sufficiently explicit.

Finally, the Air Force and OSD both failed to verify the feasibility of the proposed development and test schedule agreed on at the time of the rebaseline. It was not reasonable to expect that a program being restructured in response to cost and schedule growth, and suffering from poor performance and reliability of delivered systems, would be able to deliver multiple complex (and in some ways competing) products on a compressed schedule with a minimum of testing.

2) Management of Program Requirements

The rebaselined program also inherited the flexible approach to requirements management that had characterized the spiral development phase. The program was supposed to be working to a fixed set of explicit requirements for all blocks. Despite this fact, the program scope, cost, and schedule estimates continued to treat difficult or unfunded requirements as if they were not part of the program. This led to understatement of eventual program costs at every stage, including in the original APB estimate. It also led to deferral of work related to CDD requirements that were not currently deemed “in-scope,” with resulting inefficiencies in the acquisition sequence.

At the same time, the program was receiving conflicting requirements direction from multiple external sources. Successive ADMs directed multiple (and sometimes conflicting) shifts in development priority. Air Combat Command and the Joint Staff also directed the program to adjust development priorities. This continual redirection and reprioritization of requirements, together with confusion over which organizations had ultimate authority over requirements, led to inefficiency in the program.

Finally, the CDD requirements themselves do not conform to Department of Defense Joint Capabilities Integration and Development System (JCIDS) procedures. In particular, the program has not adopted the mandatory sustainment KPPs and KSAs:

Materiel Availability (KPP), Materiel Reliability (KSA), and Ownership Cost (KSA).[7] The reliability and maintainability requirements that existed in the original ORD—mean time between critical failures (MTBCF), mean repair time (MRT), and diagnostic fault detection—were removed from the 2006 CDD. This has contributed to the system's lack of reliability growth.

3) Management of Contractor Incentives

The contract structure of the Global Hawk program was developed during the original spiral development phase of the program, with an emphasis on flexibility rather than on accountability or performance. In particular, EMD was funded primarily through an indefinite delivery/indefinite quantity (ID/IQ) umbrella contract, with follow-on contracts that were primarily cost-plus-award-fee (CPAF) contracts.

When the program was rebaselined and restructured as a fixed-content program developing several air systems in parallel, the government had the opportunity to restructure the development and LRIP contracts to take advantage of the new certainty regarding program scope and deliverables, and to align contractor incentives more closely with successful delivery of these specified capabilities. Instead, the existing contract structure was retained, with the result that the contractor was able to earn ~80 percent of available award fees between October 2006 and September 2009, despite repeated late deliveries and performance issues.

Contracts under the Federal Acquisition Regulation (FAR) have mandatory language regarding Value Engineering Change Proposals (VECPs), including contractor incentives with specified sharing rates.[8] The general FAR provision states:

> 48.102—Policies.
>
> (a) As required by Section 36 of the Office of Federal Procurement Policy Act (41 U.S.C. 401, et seq.), agencies shall establish and maintain cost-effective value engineering procedures and processes. Agencies shall provide contractors a substantial financial incentive to develop and submit VECP's. Contracting activities will include value engineering provisions in appropriate supply, service, architect-engineer and construction contracts as prescribed by 48.201 and 48.202 except where exemptions are granted on a case-by-case basis, or for specific classes of contracts, by the agency head.[9]

The Global Hawk LRIP contracts to date do not include this mandatory provision.

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[7] *Chairman of the Joint Chiefs of Staff Manual*, CJCSM 3170.01C, Enclosure B.

[8] FAR, Part 52, Subpart 52.248-1 Value Engineering, October 2010.

[9] FAR, Part 48, Subpart 48.102, Policies.

4) Oversight of Contractor Performance

Cost reporting on the Global Hawk program has been both less complete and less timely than is usual for a program of this size. Specific issues include inappropriate Work Breakdown Structures, failure to cleanly separate costs by block, long delays in filing Contractor Cost Data Reports (CCDRs), long delays between contract award and contract definitization, and permitting the contractor to suspend Estimate at Completion (EAC) reporting. Details on cost reporting inadequacies are given on page 36 in the section entitled “Cost Reporting.”

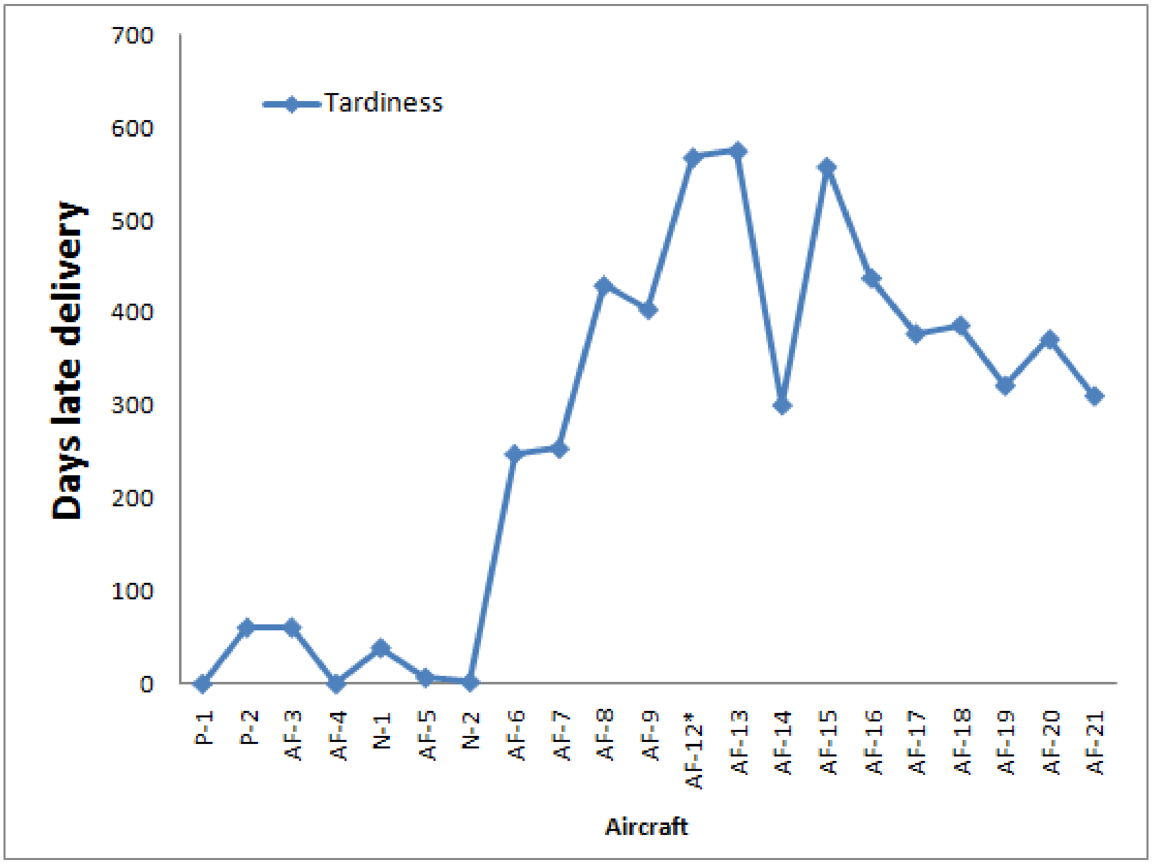
5) Funding Practices

Failure to include all CDD requirements in the baseline for the program, and failure to include all identified costs in the annual budget request, have led to persistent underfunding of the Global Hawk program. This has contributed to slow technology development and failure to cure ongoing reliability issues. Details on funding shortfalls are given below in the section entitled “Inadequate Program Funding.”

b. Contractors

1) Scheduled Deliveries

Both aircraft and sensor deliveries have been consistently far behind contracted delivery dates. As shown in Figure 4, aircraft deliveries were running more than a year late for some time, with only moderate improvement since then. This chart does not include the two most tardy deliveries, for which the program chose to accept “interim delivery” of the airframes and later delivery of the payloads.



*Battlefield Airborne Communications Node (BACN) air vehicles provided to the Navy.

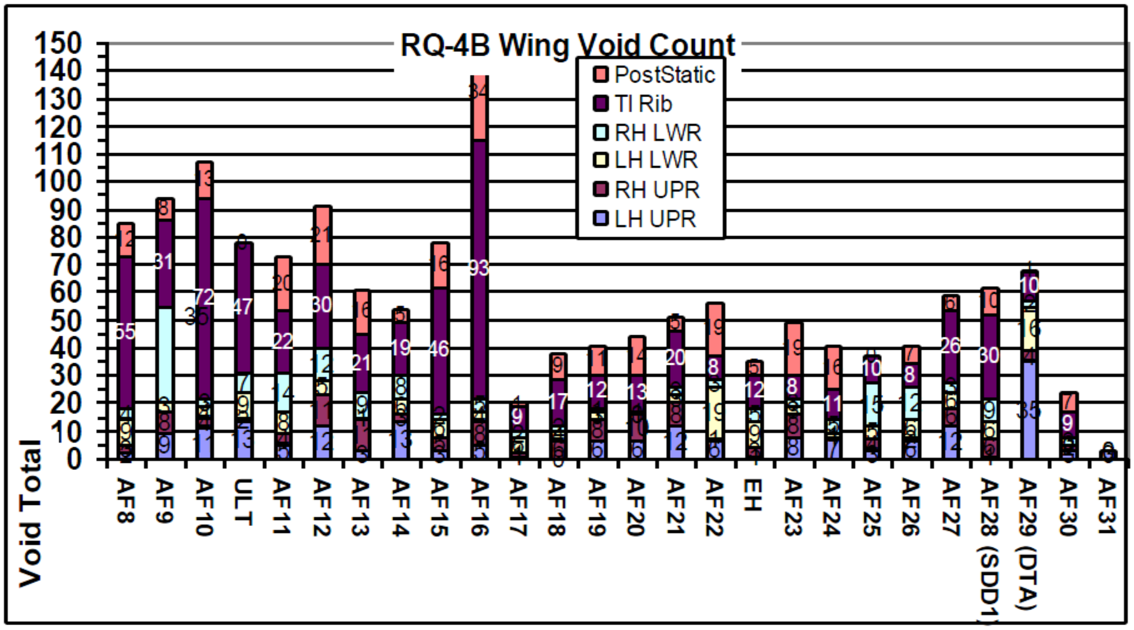
Figure 4. Airframe Delivery Tardiness

This consistent inability to meet contractual delivery obligations reflects poorly on contractor performance, and indicates deeper management issues in the program. Occasional late deliveries can be caused by many things; consistently late deliveries suggest a flawed approach, rather than flawed execution.

2) Defect Rates and Reliability

In addition to tardy deliveries, the program has also suffered from quality issues for delivered items. For example, 13 of the 15 fielded EO/IR/SAR systems suffered reliability and/or performance issues after delivery. There have also been recurring problems with actuators, power supplies, and batteries. OSD reviews of contractor systems engineering practices showed that, until recently, there was no substantive reliability tracking, failure root cause analysis, or other targeted response to these recurring issues. As of this writing, there is still no funded reliability growth initiative within the program.

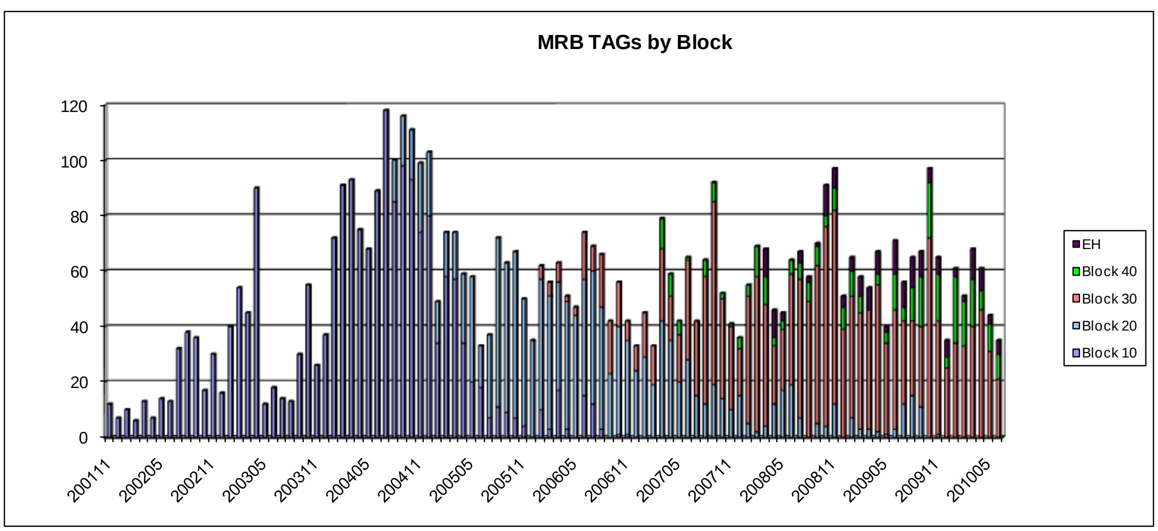
Figure 5 shows the "void count" (number of structural gap defects found on inspection by the prime contractor) for the wings of RQ-4B (Blocks 20/30/40) aircraft delivered since May 2007. While the overall trend is downward, it has taken several years to achieve this, and the absolute number of defects remains significant.



Source: Northrop Grumman, "USAF Global Hawk Production," briefing to OSD 16 July 2010.

Figure 5. Wing Void Count by Airframe

Similarly, Figure 6 shows the rate over time of Material Review Board (MRB) non-conformance adjudications, broken out by block. Since 2006, the trend has been relatively flat.



Source: Northrop Grumman, "USAF Global Hawk Production," Briefing to OSD 16 July 2010.

Figure 6. Material Review Board Negative Findings Over Time

As of August 2010, the program reported 34 CDD requirement shortfalls and 7 outstanding Category-1 Deficiency Reports (DRs). The TEMP requires that all Category-1 DRs be resolved prior to the start of IOT&E.

3) Cost Reporting

Cost reporting on the Global Hawk program has been both less complete and less timely than is usual for an MDAP.

The CCDRs for the EMD phase of the program do not distinguish recurring from nonrecurring costs—they report all costs as nonrecurring, despite the fact that several test units have been produced under the EMD contract. This makes it difficult to monitor potential hardware procurement cost growth. The EMD CCDRs also do not distinguish between the ISS and EISS sensor suites, nor do they clearly segregate development costs specific to individual blocks.

Similarly, LRIP contracts sometimes procure a mix of blocks, additional sensors, and/or ground stations, but do not clearly allocate costs among these. This makes it difficult for the program to trace cost growth to its source, or even to calculate unit costs for specific aircraft.

According to the Defense Cost and Resource Center (DCARC), Global Hawk contractors are only required to submit two CCDRs for each LRIP contract: one at initiation and one at completion. As a result, the LRIP Lot 4 contract, initiated in the spring of 2006, has not filed a CCDR since September 2006, at which time the contract was stated to be 75 percent complete. Similarly, the LRIP Lot 7 contract was awarded 22 February 2007 and was definitized 23 October 2009—but the initial CCDR for that contract was not due until 2011. Since this was the first LRIP lot to procure ASIP and MP-RTIP sensors, this means that the program office did not have any CCDR reporting of those sensor costs until four years after the contract was awarded.

The most recent CCDR filings at the time of this writing, by LRIP lot, are shown in Table 8. The last two columns show the contractor or subcontractor's estimated percentage of the work on that lot that had been completed up to that point. Despite the fact that Lot 4 delivered its last aircraft in August 2009, no final CCDR has yet been filed for that lot. As a result, cost estimates for the EISS sensor are based on out-of-date partial data, rather than actual cost data.

Table 8. LRIP Percent Complete at Latest Reporting

LRIP Lot	Initial CCDR Date	Contractor % Complete	Subcontractor (EISS) % Complete
4	September 2006	75%	62%
5	March 2007	28%	53%
6	August 2008	42%	9%
7	Not yet filed (definitized October 2009)	n/a	n/a

The Work Breakdown Structure used in the Contract Performance Report (CPR) for LRIP Lots 6 and 7 does not distinguish ASIP sensor costs from MP-RTIP sensor costs, but lumps them together as "payload segment." As above, this makes it extremely difficult to know the actual unit cost by block.

LRIP contracts for Lots 4 through 7 have filed regular CPR reports to the Central Repository, but Lots 4 through 6 stopped updating their EAC after the December 2009 report, and Lot 7 stopped updating EAC after the May 2010 report.

2. Unrealistic Cost and Schedule Estimates

The second WSARA category of root causes for cost growth is "unrealistic cost and schedule estimates." The 2007 APB estimate was unrealistic in both cost and schedule for numerous key program activities. It is difficult to separate cost growth due to poor government and contractor performance from cost growth due to unrealistic estimates. We suspect that roughly half of the APUC growth characterized as "upward revision of estimates" can be attributed to incomplete or otherwise unrealistic cost estimates at the time of the program rebaseline. That would correspond to approximately 25 percent of total APUC growth.

The most significant underestimate in the APB was not a cost estimate, but a schedule estimate. The projected time required for testing (including developmental, operational, and production acceptance testing) of aircraft and integrated ISR systems was optimistic, and inconsistent with both past history of other aircraft programs and the available test infrastructure and resources available to the program. The program's decision to combine developmental and operational testing, minimizing the number of test events, driven by the short delivery timeline, increased the program's schedule risk even further.

When testing revealed necessary redesign and rework, the test schedule provided no flexibility to recover, and schedule slips were incurred. The carefully choreographed sequence of tests became an unexecutable set of concurrent tests, with the various Global Hawk blocks competing for range time, flight hours, and test personnel. Figure 7 shows the history of the IOT&E test schedule plans for Blocks 20/30/40.

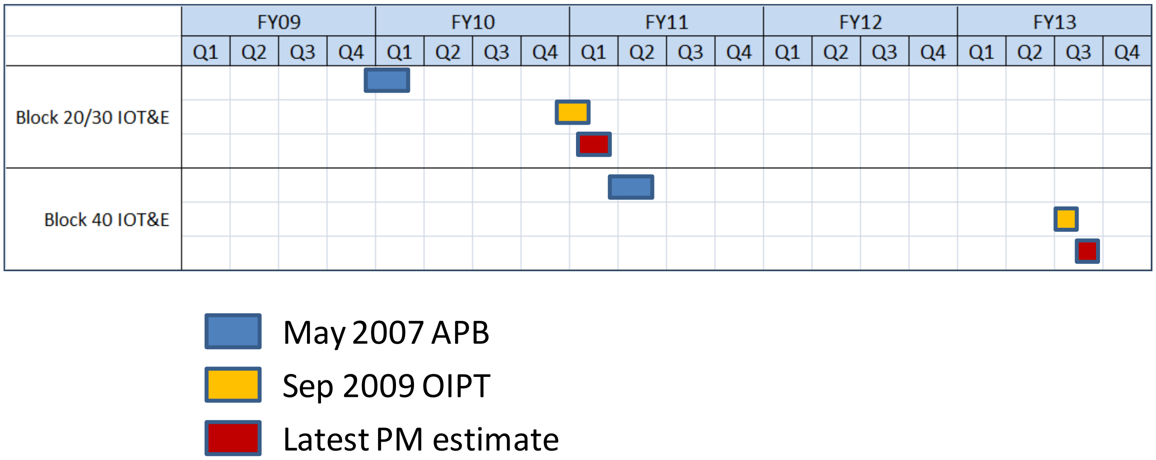


Figure 7. IOT&E Schedule History

Faced with the concurrent testing needs of three separate blocks, and already competing for test infrastructure with other programs at Edwards AFB, the Global Hawk program decided to increase test capacity by building and staffing new dedicated test infrastructure at Beale AFB, building a new PAT facility at the contractor's Palmdale site, and building a new anechoic chamber facility to support calibration of the ASIP sensor. These unplanned facilities costs contributed directly to APUC growth.

In addition to unplanned facilities costs, overall program delay led to increased procurement costs in other ways. Obsolescence of certain electronic and software components meant that some DMS mitigation activities, originally planned for the O&S phase of the program, had to be paid for with procurement funds. The stretching of the test-fix-test cycle for Block 30 and Block 40 LRIP led to a higher proportion of SE/PM costs than before, increasing APUC further.

The APB cost estimate did not reflect the risk inherent in the APB schedule. There is some evidence that the Independent Cost Estimate (ICE) that the program adopted as its cost baseline was developed prior to the establishment of that schedule. In either case, there is a lesson to be learned about the mutual dependence among cost, schedule, and risk when establishing a program baseline.

The APB estimate also featured unrealistic cost estimates for ASIP and MP-RTIP payloads, and for ECOs. Program office estimates of the recurring unit cost of ASIP and MP-RTIP sensors have increased by roughly 20 percent since the 2007 APB. While some of this growth may be due to technical issues, the contractor has not reported any major redesigns to account for a significant increase in projected unit recurring costs. This suggests that the original baseline cost estimate was unrealistically low. Similarly, ECOs have consistently run at a higher level than predicted in the baseline estimate, which was developed using analogies with past aircraft programs that were less programmatically complex, and had fewer external dependencies and schedule pressures, than the Global Hawk program.

3. Unanticipated Technical Issues in Program Execution

The third important WSARA root cause for cost growth in the Global Hawk program has been "unanticipated technical issues in program execution." Technical issues have been a significant driver of schedule slip in the Global Hawk program, resulting in cost growth in many areas. Integration, reliability, and performance to CDD threshold standards have all proven to be more challenging than anticipated. This has led to increased costs for sustaining engineering, program management, integration, assembly, checkout, and test (IACT), reliability engineering, DMS mitigation, and PAT.

Unanticipated technical issues affect costs primarily through the combined effects of increased program duration and higher procurement burn rates. The prime contractor's SE/PM burn rates are high (compared to historical programs) and still growing, in part in response to technical challenges in the program. In addition, planned sensor retrofit costs have also risen over time, driven by technical issues in sensor development and integration.

4. Inadequate Program Funding

The fourth WSARA root cause applicable to Global Hawk is "inadequate program funding." There has been a persistent discrepancy over time between the amount of funding required for the Global Hawk program to meet its CDD requirements and delivery schedule, the funding requested by the program, and the funding profile in the SAR and President's Budget. The discrepancy has two primary components:

- Requirements not included in program cost estimates
- Requirements identified by the program but not funded in the Air Force budget

a. Missing Requirements

When the cost to meet a known requirement is not included in program office procurement estimates, it also is not funded in the budget. When these requirements eventually are acknowledged, and costs to implement them are included in the estimate, the result is instant cost growth. This has been the pattern with numerous CDD requirements for the Global Hawk program, including JTRS integration, Wideband Gapfiller Satellite (WGS) interoperability (via FAB-T), multi-day encryption, and multi-aircraft control. The known instances of delayed recognition of requirements are enumerated above in section D.3, "Baseline Program Content Missing in the Baseline Estimate."

b. Unfunded but Known Requirements

Even when requirements were acknowledged within program office cost estimates, the corresponding funding requirements did not always survive into the Air Force POM submission. This resulted in underfunding of work that was known to be in-scope, which in turn led to schedule delays, technical issues, and other indirect areas of cost growth. The impact was greatest when the activities that were underfunded were systems engineering and testing activities whose absence contributed to later reliability shortfalls, performance issues, and unplanned rework. Reliability and performance issues, in turn, led to increased costs for initial spares.

5. Increased Procurement Quantities of the More Expensive Global Hawk Variants

The most straightforward WSARA root cause of APUC growth in the Global Hawk program is the growth due to increasing the fraction of Block 30 and Block 40 aircraft in the total buy. The increase in APUC is due simply to arithmetic, not to any underlying change in what a Block 30 or Block 40 aircraft is expected to cost. However, this cost growth due to the changing aircraft mix is augmented by the fact that Block 30 and Block 40 unit costs are also growing faster than those of other blocks. In this analysis, we have isolated the cost growth due solely to the decision to procure additional Block 30 and Block 40 aircraft. We have addressed the growth due to unit cost increases in those blocks in the various other root causes discussed above. It is worth noting again that, in a typical program, this cost growth would have been offset by unit cost reductions due to increased learning and spreading of nonrecurring costs over a larger number of units. In the Global Hawk program, neither of these offsetting effects is present.

F. Looking Forward

Several recurring themes arose during our analysis of the Global Hawk program and how it arrived at its current status. The first theme was the disconnect between the behaviors and outcomes most desired by the government, versus the behaviors and outcomes for which priorities were set and incentives were offered, both for the contractors and for the program office. The second theme was a diffusion of accountability within the acquisition process, at all levels of authority. Finally, while this report describes a root cause analysis of cost growth identified to date, in the course of our investigation we also identified a number of areas in which we anticipate additional cost growth in the future. We conclude our analysis with a forward-looking discussion of each of these themes in turn.

1. Incentives

At the time of the 2007 APB, the government's desires for the Global Hawk program were straightforward: they wanted suitable, affordable, and operationally effective aircraft systems of three distinct types, delivering specified capabilities, on a schedule that would support certain planned activities outside the Global Hawk program. (Whether it was reasonable to believe that this schedule was reasonable, given the history and status of the program in 2007, is a separate question.) The government also had priorities among the variants, driven primarily by those external planned activities. A well-designed acquisition strategy would, at a minimum, have rewarded contractors for delivering suitable and operationally effective aircraft in a timely fashion, in accordance with government priorities, and would have penalized (or at least failed to reward) contractors for unsuitability, ineffectiveness, tardiness, or priorities clearly inconsistent with the stated government priorities. Instead, the contract and incentives structure from the earlier spiral development phase of the program were retained. Figure 4 (on page 34) shows the history of tardy deliveries of aircraft. This chart does not include the two most tardy deliveries, which were sufficiently late that the program office accepted "interim deliveries" without the payloads. Asterisks on the figure indicate BACN air vehicles provided to the Navy. It is clear that not only were initial delivery promises optimistic, but there has been no sustained improvement over time.

The Global Hawk program could have done more to align the contractor's financial interest more closely with the government's interest, especially at the time of the rebaseline. Incentive fees, with incentives based on satisfactory contractor performance, were not used for EMD.

2. Accountability

The program and contractor are only partly responsible for the lack of focus and coordination toward achieving program success. Since the time of the 2007 APB, the program has been subject to management and directives from multiple organizations within the Air Force, the Joint Staff, and the Office of the Secretary of Defense. Numerous ADMs have modified procurement quantities, reprioritized technology development efforts, changed test and evaluation criteria, and introduced new reporting requirements. Funding levels have been persistently too low, exacerbated by the program's failure to acknowledge required content in their cost estimates and the Air Force's tendency to reduce their POM submission for the program below the program office estimate.

In the independent panel review of the 2010 Quadrennial Defense Review,[10] the panel notes that:

> To address the most fundamental cause of disappointing acquisition performance, it will be necessary to replace the current diffused, fragmented assignment of responsibilities without accountability with authority and accountability vested in identified, authoritative individuals in line management. To repeat: the emphasis must be on individuals in line management. Although more competence in writing and negotiating contracts is desirable, the key to effective execution of any contract is not the quality of the contract, it is the quality of the program management responding to clear assignment of authority and accountability for each program.

The Global Hawk program provides a model for the issues to which the panel was responding and how those issues affect cost, schedule, and performance. The fragmented authorities and inconsistent direction led to genuine confusion about the content of the program at any given time, the activities that should have priority, the costs that were included in a given cost estimate, and the required capabilities of the various blocks.

The most striking example of this lack of accountability has been the consistent mismatch between validated program technical content (as captured in the CDD, CARD, TEMP, and ASR), the content assumed by the APB estimate and annual Program Office Estimates, the content funded in the Air Force POM submissions, and the content funded in the President's Budgets. Each of these mismatches is a failure of the acquisition oversight process. The cumulative result has been to repeatedly mislead OSD, the public, and the Congress about what capability can be acquired for what cost.

3. Potential Future Cost Growth

This analysis has focused on identifying root causes of past and current APUC growth, in accordance with the mission of PARCA. In the course of that analysis, we identified some factors that we believe will continue to cause costs to grow, or that have not yet led to cost growth but may do so in the future. In this final section, we discuss several of these potential areas of future cost growth.

a. Missing Requirements

Although the program has recently acknowledged the costs to achieve many CDD requirements in their proposed Communications Rearchitecture and Ground Station Rearchitecture plans, those efforts do not yet address all of the date-specified CDD requirements for Blocks 10–40. Several of those requirements, such as Sense-and-Avoid

[10] "The QDR in Perspective: Meeting America's National Security Needs in the 21st Century," July 2010.

capability, are necessary to achieve threshold KPPs or KSAs. In June 2010, Headquarters Air Combat Command briefed a list of "Unfunded Thresholds" that included the following 25 capabilities that Air Combat Command considered not yet fully funded in Global Hawk cost estimates:

1. EISS Maritime Mode and STANAG [Standardization Agreement] formatting.
2. Range increase (more than double) for EO and IR on EISS.
3. GMTI [Ground Moving Target Indicator] on EISS/SAR.
4. Radar Canting.
5. LPI [Low Probability of Intercept]/LPD [Low Probability of Detection] Locating Systems.
6. JTRS.
7. Three, secure, jam-resistant UHF/VHF [Very High Frequency] nets simultaneously.
8. Capability for use of Transmission Control Protocol (TCP) IP [/Internet Protocol] for secure C^2 data transmission during terrestrial reachback operations.
9. Incorporation of a wideband air to air (network and point to multipoint) and a wideband broadcast capability for secure LOS [Line-of-Sight] communication of payload data.
10. Incorporation of a wideband air to air (network and point to multipoint) and a wideband broadcast capability for secure LOS communication of….C^2 data.
11. Capability to use the Transformational Communications Architecture (TCA) SATCOM/optical components for BLOS [Beyond-Line-of-Sight] secure payload data transmission, BLOS secure voice communications, and BLOS secure C^2 communications.
12. The system will be interoperable with appropriate communications standards and directives, including, but not limited to….Network CDL [Common Data Link] (N-CDL) and Advanced CDL (A-CDL).
13. CNS [Communications, Navigation, and Surveillance]/ATM [Air Traffic Management] Fulfillment.
14. Sanitize Classified.
15. Engine Restart.
16. Aircraft and payloads must be protected against…extreme temperature ranges, biological and chemical threats.

17. The payload will provide a data stream of an appropriate classification level (currently secret collateral) that allows machine to machine interface.
18. To optimize horizontal payload integration for rapid precision targeting, the Global Hawk system must provide direct and/or indirect automated machine-to-machine cues among internal sensors and to other command and control, intelligence surveillance and reconnaissance (C^2ISR) platforms/nodes.
19. To optimize horizontal payload integration for rapid precision targeting, the Global Hawk system…. must be able to accept similar communications.
20. The aircraft must include a capability that permits mission accomplishment without reliance on LOS or BLOS data transfer (i.e., a capability for “off-tether” operations). (KSA) SIGINT.
21. SIGINT Compression and SIGINT Recording.
22. Ground station operators must be able to….receive and respond to….advisory support messages normally transmitted over high frequency (HF) systems.
23. The system must have the capability to provide payload control to other multi-service or joint exploitation facilities.
24. The aircraft must be equipped to detect radar-guided threats as identified in the STAR [Sense, Track, and Avoid Radar] and relay the information to ground station personnel.
25. The aircraft should be equipped to employ active countermeasures against radar and IR-guided threats to the system as identified.

Some of these requirements (e.g., JTRS) appear to be at least partially funded in the 2009 SAR. However, December 2009 Program Office briefings state that the Sense-and-Avoid capability (Worldwide Operations KPP), certified CDL (Net Ready KPP), and infrared sensor performance (Battlespace Awareness KPP) will only be addressed post-IOT&E. Total and unit cost estimates will grow again when any of these capabilities are explicitly acknowledged as required program content.

b. Schedule Risk

The development and testing concurrency that has led to schedule delays will continue into the future. The additional PAT facilities will partially alleviate this, but competition for DT and OT resources will continue. Increasing efforts associated with the BACN Joint Urgent Operational Need (JUON), the Navy BAMS program, and the Eurohawk FMS program will only add to this. Engineering support resources may also be stretched thin in support of these parallel efforts, leading either to delays or to further increases in the sustaining engineering load of the program. Finally, there remain technical challenges in aircraft, sensors, and integration to be overcome. For these reasons, we think it likely that additional schedule slips (with corresponding cost growth) will occur.

c. Reliability

The Global Hawk program has no detailed component or system reliability requirements, but the ETOS KSA threshold of 85 percent has many implications for necessary component and system reliability. Testing to date has found that none of the blocks comes close to achieving the necessary time between failures to achieve the 85 percent goal. We anticipate that a dedicated reliability growth program will be necessary to identify redesigns and improvements in manufacturing that would allow Blocks 20/30/40 to meet their required level of persistent ISR. This would be followed by a retrofit program to upgrade previously delivered aircraft. Costs to fund and execute a reliability growth program and associated rework/retrofits will likely cause additional total and unit procurement cost growth in the program.

d. Sensors

Actual recurring costs to produce the EMD units for MP-RTIP and ASIP have been significantly higher than projected, even when allowing for future cost reduction through “learning curve” behavior. If these costs prove to be representative, unit costs of MP-RTIP and (to a lesser extent) ASIP sensors will be higher than current estimates, leading to total and unit procurement growth.

e. Outyear Support

The Global Hawk December 2009 SAR projects that procurement and retrofit activities will continue through 2024, but that support funding will effectively end after 2015. This seems unlikely; it is more likely that support will be needed for as long as the program is continuing to retrofit aircraft, especially since these ‘retrofits’ include the initial installation and integration of ASIP sensors on 11 Block 30 aircraft. Figure 8 shows the SAR funding projection. “EI” and “NEI” stand for “End Item” and “Non-End Item,” respectively. The program office considers ASIP sensors to be retrofit on Block 30I aircraft as “Non-End Item” components. We would expect additional support funding to be required at roughly FY 2012 levels for at least 10 more years.

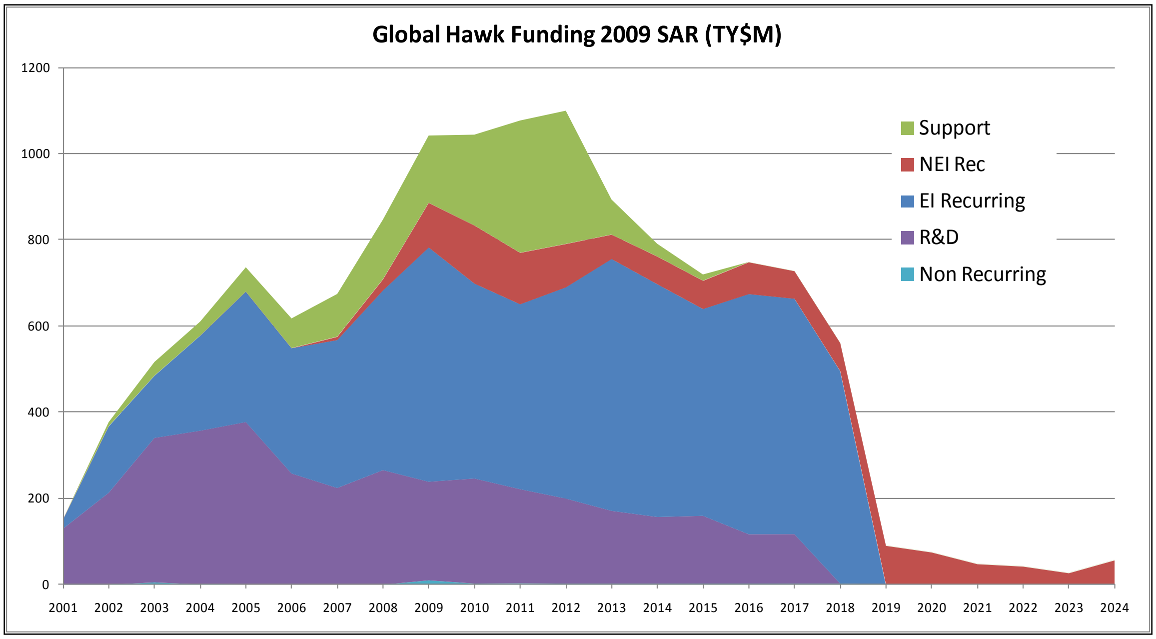


Figure 8. Probable Outyear Support Funding Growth

Illustrations

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Abbreviations

AC	Aircraft
ACTD	Advanced Concept Technology Demonstration
ADM	Acquisition Decision Memorandum
ADS-A	Automatic Dependent Surveillance-Addressed
AFOTEC	Air Force Operational Test and Evaluation Center
AGS	Alliance Ground Surveillance
AMF	Airborne/Maritime/Fixed
APB	Acquisition Program Baseline
APUC	Average Procurement Unit Cost
ASD(A)	Assistant Secretary of Defense for Acquisition
ASIP	Airborne Signals Intelligence Payload
ASR	Acquisition Strategy Report
AT&L	Acquisition, Technology and Logistics
ATM	Air Traffic Management
BACN	Battlefield Airborne Communications Node
BAMS	Broad Area Maritime Surveillance
BLOS	Beyond-Line-of-Sight
C^2	Command and Control
C^2ISR	Command and Control Intelligence, Surveillance, and Reconnaissance
C^3ISR	Command, Control, Communication, Intelligence, Surveillance, and Reconnaissance
CA	Cost Analysis
CAP	Combat Air Patrol
CAPE	Cost Analysis and Program Evaluation
CARD	Cost Analysis Requirements Description
CCDR	Contractor Cost Data Report
CDD	Capability Development Document

CDL	Common Data Link
CER	Cost Estimating Relationship
CNS	Communications, Navigation, and Surveillance
COMSEC	Communications Security
CONOPS	Concept of Operations
COTS	Commercial Off-the-Shelf
CPAF	Cost-Plus-Award-Fee
CPDLC	Controller Pilot Data Link Communications
CPR	Contractor Performance Report
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DARPA	Defense Advanced Research Projects Agency
DCARC	Defense Cost and Resource Center
DCMA	Defense Contract Management Agency
DMS	Diminishing Manufacturing Sources
DoD	Department of Defense
DOT&E	Director, Operational Test & Evaluation
DR	Deficiency Report
DT	Developmental Testing
EAC	Estimate at Completion
ECO	Engineering Change Order
EI	End Item
EISS	Enhanced Integrated Sensor Suite
EMD	Engineering and Manufacturing Development
EO	Electro-Optical
ETOS	Effective Time on Station
ETP	Extended Tether Program
FAB-T	Family of Advanced Beyond-Line-of-Sight Terminals
FANS	Future Air Navigation System
FAR	Federal Acquisition Regulation
FMS	Foreign Military Sales
FOB	Forward Operating Base

FRP	Full Rate Production
GATM	Global Air Traffic Management
GMTI	Ground Moving Target Indication
GPS	Global Positioning System
GWoT	Global War on Terror
HAE	High Altitude Endurance
HAT	High Altitude Transition
HF	High Frequency
IACT	Integration, Assembly, Checkout, and Test
ICE	Independent Cost Estimate
ID/IQ	Indefinite Delivery/Indefinite Quantity
IDA	Institute for Defense Analyses
IFF	Identification Friend or Foe
IMINT	Image Intelligence
IMS	Integrated Master Schedule
IOT&E	Initial Operational Test & Evaluation
IP	Internet Protocol
IR	Infrared
ISR	Intelligence, Surveillance, and Reconnaissance
ISS	Integrated Sensor Suite
JCIDS	Joint Capabilities Integration and Development System
JROC	Joint Requirements Oversight Committee
JTRS	Joint Tactical Radio System
JUON	Joint Urgent Operational Need
KPP	Key Performance Parameter
KSA	Key System Attribute
LOS	Line-of-Sight
LPD	Low Probability of Detection
LPI	Low Probability of Intercept
LRE	Launch and Recovery Element
LRIP	Low Rate Initial Production
MCE	Mission Control Element

MDAP	Major Defense Acquisition Program
MOB	Main Operating Base
MP-RTIP	Multi-Platform Radar Technology Insertion Program
MRB	Material Review Board
MRT	Mean Repair Time
MTBCF	Mean Time Between Critical Failures
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NEI	Non-End Item
NSA	National Security Agency
O&S	Operations and Support
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OIPT	Overarching Integrated Product Team
OPTEMPO	Operational Tempo
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OT	Operational Testing
PARCA	Performance Assessments and Root Cause Analyses
PAT	Production Acceptance Testing
PAUC	Program Acquisition Unit Cost
POE	Program Office Estimate
POM	Program Objective Memorandum
PSE	Peculiar Support Equipment
QDR	Quadrennial Defense Review
RDT&E	Research Development Test & Evaluation
RNP-4	Required Navigation Performance Level 4
SAR	Selected Acquisition Report
SAR	Synthetic Aperture Radar
SE/PM	Systems Engineering and Program Management
SIGINT	Signals Intelligence
STANAG	Standard Agreement

STAR	Sense, Track, and Avoid Radar
TCA	Transformational Communications Architecture
TCDL	Tactical Common Data Link
TCP	Transmission Control Protocol
TEMP	Test and Evaluation Master Plan
TFT	Tactical Field Terminal
TIGDL	Tactical Interoperable Ground Data Link
TPM	Technical Performance Metric
U.S.	United States
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UHF	Ultra High Frequency
USAF	United States Air Force
VECP	Value Engineering Change Proposal
VHF	Very High Frequency
WGS	Wideband Gapfiller Satellite / Wideband Global SATCOM
WSARA	Weapon Systems Acquisition Reform Act

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Bronson, Patricia F.
Fox, Jeffrey N.
Kodzwa, Paul M.
Tate, David M.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
In May 2007, Office of the Principal Deputy Under Secretary of Defense (Acquisition, Technology and Logistics) asked the Director, Performance Assessments and Root Cause Analyses (PARCA) to perform a root cause analysis of anticipated unit cost growth in the Global Hawk unmanned aircraft system program. This request was based on a cost growth estimate performed by CAPE-CA, the cost analysis group within the Cost Analysis and Program Evaluation (CAPE) directorate of the Office of the Secretary of Defense. That cost estimate concluded that average procurement unit cost (APUC) for the Global Hawk program has grown by more than 20 percent since the program was restructured in 2007. PARCA asked IDA to identify the root causes of the APUC growth identified by CAPE-CA, in accordance with the root cause analysis guidelines established in the Weapon Systems Acquisition Reform Act of 2009 (WSARA). This report describes our analysis and findings related to that task.

15. SUBJECT TERMS
PARCA, Root Cause Analysis, Global Hawk, APUC, Cost Growth, Requirements, Cost Estimating, UAS

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