Chapter Three

GLOBAL HAWK

PHASE II ENGINEERING DEVELOPMENT

According to the earliest program documentation, Global Hawk flight testing was scheduled to begin in December 1996.[1] As of September 1997, however, the integrated mission management computer (IMMC) software was not yet ready for taxi or flight. Such problems were tracked by the DARPA JPO at its monthly Home Day meetings and were documented in the briefing charts supporting those meetings. As previously discussed, software development and integration problems contributed significantly to the 14-month delay of the first flight, which occurred on February 28, 1998.[2]

The pace of the flight test program was largely determined by the fact that Global Hawk is both a large, complex airplane and an autonomous UAV. For the most part, the character of the system determined the design and execution of the engineering portion of the flight test program.

Development testing constituted the first 21 flights, the last three of which (flights 10–12 for air vehicle 1) were considered follow-on

[1]See Drezner, Sommer, and Leonard, *Innovative Management in the DARPA High Altitude Endurance Unmanned Aerial Vehicle Program*, Table 3.3, 1999, p. 55. DARPA's *HAE UAV ACTD Management Plan*, December 15, 1994, and Teledyne Ryan Aeronautical's *Master Test Plan*, November 17, 1995, indicated a planned first flight in January 1997, a one-month difference.

[2]See Drezner, Sommer, and Leonard, *Innovative Management in the DARPA High Altitude Endurance Unmanned Aerial Vehicle Program,* 1999.

DT.[3] Flight 13 of air vehicle 1, conducted on June 19, 1999, was the first D&E flight test. The Phase II engineering development flights roughly accomplished what a traditional demonstration/validation program would. All subsequent flights during Phase III were dedicated to demonstrating the operational system, performing functional checkout of additional air vehicles, or testing configuration improvements. The demonstration flights are unique to the ACTD process. The configuration change test and functional checkout flights are EMD-type activities.

Figure 3.1 shows the gradual buildup of flight hours during Phase II testing. Air vehicles 1 and 2 flew a combined total of 21 sorties over a 16-month period, accumulating 158 flight hours. Air vehicle 1 flew 12 sorties for 103 flight hours; air vehicle 2 flew nine sorties, accumulating 55 flight hours. Flight 11 of air vehicle 1, the 20th sortie of the program, was the longest, lasting 27.2 hours. Air vehicle 1 mainly flew airworthiness sorties, while air vehicle 2 primarily flew payload checkout sorties.

The first aircraft explored the entire flight envelope in five flights. Each additional aircraft required approximately three productive flights to be completely checked out in the envelope. The only true expansion of the flight envelope occurred when the elapsed time was extended at higher altitudes, as the possibility of extremely cold temperatures at such altitudes had the potential to stress the system. Flight test personnel at EAFB commented that it took them nine sorties using air vehiicle 1 to get comfortable with the system.

All Phase II flights were either airworthiness (11) or payload (10) functional checkout flights. Objectives were not met in four of the 21 flights (one airworthiness and three payload). Objectives were at least partially met in the other 17 sorties. In cases where objectives were not met, the mission was generally reflown. If only one or two objectives from the list for a specific flight were not met, these were often added to the next mission.

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[3]Although the program had planned to fly the initial flights at a faster rate, it ended up under budget owing to a slower-than-planned increase in pace and to delayed hiring of additional test personnel.

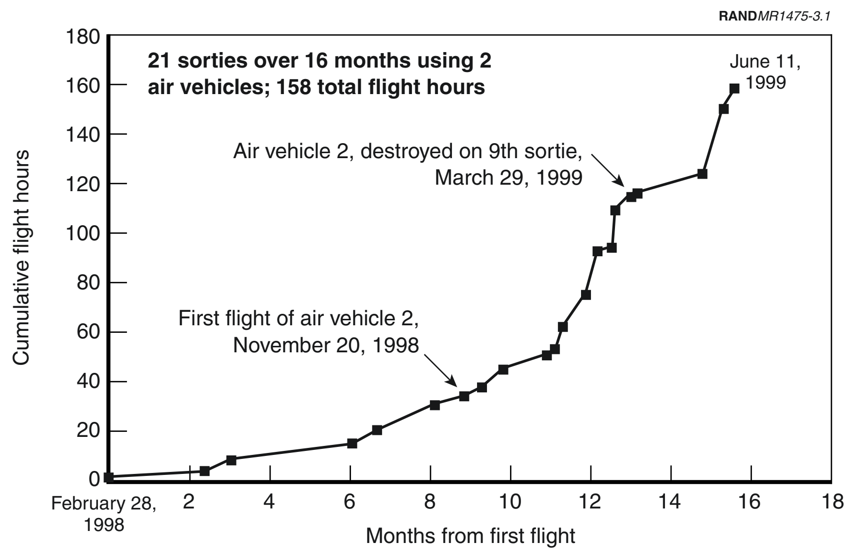

Figure 3.1—Phase II Global Hawk Flight Test Program

Engineering development tests for Global Hawk occurred in both Phase II and Phase III of the ACTD. Development tests culminated in certification that Global Hawk was ready for operational testing; this was called the Phase II assurances process. Phase II assurances provided the HAE UAV Oversight Council sufficient information to approve entry into the next phase.[4]

The Phase II flight test program did slip by several months. The original plan called for a 12-month program; the actual program was 16 months. Phase II was to be completed when program management transitioned from DARPA to the Air Force, which actually took place in October 1998. The phase was actually completed some nine months later, when the first Phase III D&E flight took place in June 1999. Phase II testing did accomplish the majority of its objectives, as it allowed for an initial characterization of both air vehicle and synthetic aperture radar (SAR) performance. However, the program

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[4]Command, Control, Communications, Computers, and Intelligence Support Plan (C4ISP) final report, November 15, 2000.

did not demonstrate the ability to control two Tier II+ air vehicles at a time. Nor did the program test the electro-optical/infrared (EO/IR) sensor sufficiently to characterize its performance; the only EO/IR subsystem available at that time was lost in the destruction of air vehicle 2.

Contractor Test Responsibilities

The contractors (Lockheed Martin Skunk Works [LMSW] and Ryan) were given significantly increased responsibilities in the conduct of the flight test program. This included designating the test director and taking the lead for test planning and execution, with assistance from AFFTC at EAFB for safety issues and from ACC for technical support. This arrangement is consistent with Other Transaction (OT) implementation in this program. The arrangement increased demands on contractor flight test personnel while reducing them on flight test center personnel.

The original flight test director at Ryan had no experience with large aircraft programs. However, the current Ryan flight test director at EAFB, who was hired in January 1997, played a critical role in shaping the Global Hawk flight test program and its execution. On the basis of his experience in the Air Force on the Lightweight Fighter (LWF) program,[5] he involved user representatives—the 31st TES from ACC—in all aspects of flight testing in efforts to introduce an operational flavor.[6] He did this over the objection of the Ryan program manager at the time. In the end, Ryan, the government program office, and the 31st TES collaborated to get the 31st more involved.

The contractor's extensive test responsibilities appear to have had little substantive effect on the Phase II engineering development flight test program. This is not surprising given that contractor flight testing is the norm in early engineering development. Decisionmaking was perhaps a little faster, but interagency coordi-

[5]The LWF program was one of several streamlined competitive prototyping efforts run by the Air Force in the early 1970s. This program, which included the YF-16 and YF-17, is considered particularly successful in that both prototypes led to new operational systems.

[6]The LWF did this by including operational pilots.

nation was somewhat more difficult. In any case, government agencies (the Global Hawk System Program Office [GHSPO] and AFFTC) played significant roles in the execution of the flight test program, and the SPO supported Ryan in its test planning responsibility.

Destruction of Air Vehicle 2

The major setback during Phase II flight testing was the destruction of air vehicle 2 on March 29, 1999, during the program's 18th sortie. The loss of air vehicle 2 and its payload was estimated at $45 million. Of more importance, however, was the fact that the program lost its only integrated sensor suite. The crash was due to a lack of proper frequency coordination between the Nellis Air Force Base and EAFB flight test ranges. Essentially, Nellis officials who were testing systems in preparation for Global Hawk's first planned D&E exercise were unaware that Global Hawk was flying over China Lake Naval Air Weapons Station, which is within EAFB's area of responsibility. When Nellis tested the flight termination code, Global Hawk responded exactly as designed.

Air Force frequency management procedures were not designed to accommodate an autonomous high-altitude UAV. High-altitude flight creates a much greater distance for receiving line-of-sight commands. The absence of a human in the loop, either onboard the aircraft or on the ground, did not permit the unintended flight termination command to be disregarded. The procedures that allowed these circumstances to arise were thus an Air Force–wide problem rather than one specific to Global Hawk. These procedures were changed as a result of this accident, thereby precluding a similar incident in the future.[7]

One circumstance leading to the destruction of air vehicle 2 was the contractor's decision to refly on Monday the sortie that had been aborted three days before. Some participants believe that the flexibility to execute the reflight so quickly stemmed from the contractor's status as lead for test program execution. Others believe that

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[7]Excerpted from the Accident Investigation Board report released on December 22, 2000. See "Poor Communications Management cited in Global Hawk UAV Crash," *Inside the Air Force*, Vol. 11, No. 1, January 7, 2000, pp. 9–10.

the Air Force would have made the same decision and executed the same quick turnaround. Most participants stated that the destruction of air vehicle 2 was not a result of contractor involvement in the test program because Ryan relied on AFFTC for test support in any case. However, the incident report states that Ryan did not follow established notification procedures for the revised mission. Some participants further noted that Ryan had in fact followed these procedures and had provided the necessary information to the appropriate office at EAFB. Unfortunately, the person who normally handles frequency management coordination at EAFB was on leave that day. Other participants noted that had AFFTC been the RTO, it might not have approved the Saturday workload that was required to support a Monday flight owing to manning and flight operational tempo issues. Considering all of these views, it is not clear if the contractor's designation as lead for test program execution played a role in the loss of air vehicle 2.

PHASE III DEMONSTRATION AND EVALUATION

Global Hawk progressed into the Phase III user D&E phase in June 1999. DarkStar was terminated in January 1999, well before the completion of its engineering flight tests or the start of the D&E period.

Phase III D&E focused on generating information to support the MUA. Although the bulk of the Phase III effort was devoted to planning and executing D&E exercises, some flights supported engineering testing for vehicle functional checkout and acceptance, sensor checkout, and wing pressure validation. Other sorties supported both follow-on engineering development and D&E exercises, as tests were performed as the air vehicle transited to its position in support of a given D&E exercise.

The D&E IPT operations plan dated September 1997 documents the MUA process envisioned at that time. Both USACOM and ACC participated on the IPT and in the development of the plan, with USACOM acting as the chair and ACC providing personnel and some post-ACTD operations planning. Data taken from the D&E flights were intended to serve three purposes: (1) to inform the MUA; (2) to support the post-ACTD decision process; and (3) to characterize the ACTD configuration capability for use of the residual assets.

Effectiveness, suitability, and interoperability were the three top-level operational parameters considered in the MUA. From these, operational issues were derived, each of which had several subobjectives and associated metrics. An assessment plan was developed for each exercise, and the results were documented in an after-action report. The results documented in each after-action report were combined into the overall assessment. The entire process, including the details of objectives and subobjectives, data collection methods, and recommended training for data collection personnel, was documented in the Integrated Assessment Plan (IAP) dated June 1998.

Given the complexity and novelty of this undertaking, the MUA process described in these later documents appeared reasonable. However, there were some noticeable gaps. Absent from the IAP, for example, was a more precise description of how the information generated during the exercises would be used in the MUA. Also omitted was information on the relative importance of the objectives and subobjectives of the MUA determination and details on how the information gained would support requirements generation and post-ACTD planning.

When Phase III D&E was shortened as a result of schedule slips in other aspects of the program, USACOM/JFCOM expressed concern regarding the adequacy of the information that would be generated by the diminished number of exercises and flight hours. It was feared that the abbreviated flight test program would not support a definitive MUA.

In the shortened Phase III, quick-look reports were produced after each demonstration exercise. These reports, written by AFOTEC Detachment 1, documented key experiences during each demonstration and noted key problems. The information collected at each exercise differed depending on the objectives laid out in the assessment plan for that exercise. In general, the quick-look reports were carefully done and consistent both across demonstration exercises and with IAP criteria and procedures. These documents were synthesized in a series of sequenced, cumulative reports entitled "crawl," "walk," and "run"/final, forming the basis of the final MUA document. The process for aggregating and communicating the results of the D&E was revised from the original plan to this approach, providing incremental reports.

Figure 3.2 shows cumulative flight hours for the Global Hawk Phase III flight test program. Over a 13-month period, 37 sorties were flown, yielding a total of 554 flight hours. Four air vehicles were used, never more than one at a time. The LRE and the MCE used in Phase II were supplemented by two additional LREs and one additional MCE during Phase III in a Global Hawk–only configuration.[8]

D&E missions accounted for 21 sorties supporting 11 exercises that totaled 381 flight hours. The exercises in which Global Hawk participated were as follows:

- Roving Sands 1 (June 19, 1999)
- Roving Sands 2 (June 26, 1999)
- Roving Sands 2B (June 27, 1999)

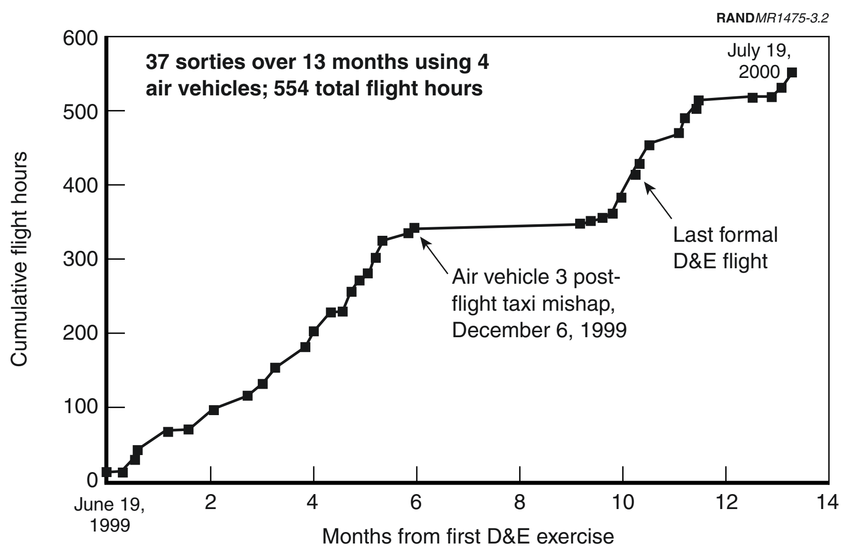

Figure 3.2—Global Hawk Phase III Flight Test Program

[8]MCE 2 and LRE 2 were already configured in the CGS design that incorporated DarkStar functionality. They were in various stages of final integration when DarkStar was terminated. Both units were returned to Raytheon for removal of DarkStar functionality and for subsequent redesign into a Global Hawk–only configuration.

- Extended Range 1-1 (July 15, 1999)
- Extended Range 1-2 (July 27, 1999)
- Extended Range 2/JEFX/Combined Arms Exercise (CAX) (August 30, 1999)
- CAX 99-10 U.S. Marine Corps Exercise (September 9, 1999)
- Extended Range U.S. Navy Seals (October 4, 1999)
- Extended Range 3-02 U.S. Navy Seals and close air support (CAS) (October 8, 1999)
- Extended Range 4-01 Alaska (October 19, 1999)
- Extended Range 4-02 Alaska (October 25, 1999)
- Desert Lightning II (November 9, 1999)
- Desert Lightning II (November 13, 1999)
- Desert Lightning II (November 17, 1999)
- Joint Task Force (JTF)-6 Sortie 1 (December 3, 1999)
- JTF-6 Sortie 2 (December 6, 1999)
- D&E Deployment to Eglin Air Force Base (April 20, 2000)
- Linked Seas–1 (May 8, 2000)
- Linked Seas–2 (May 11, 2000)
- Joint Task Force Exercise (JTFEX)00-1 (May 18, 2000)
- JTFEX00-2 (May 19, 2000)

A number of these D&E flights represented reflights of unsuccessful or partially successful prior sorties. Roving Sands 2B was a reflight of the previous mission, which was curtailed when the SAR would not come online. The third Desert Lightning II flight was a refly of the previous mission, which was curtailed owing to an IMMC failure. The JTF-6 Sortie 2 mission was curtailed, and a safe landing was accomplished using a contingency flight and landing profile, after which the Air Vehicle 3 taxi accident occurred as the aircraft was preparing to taxi off the runway. This accident led to a stand-down of all flight testing from December 1999 to March 2000.

The first four D&E exercises (Roving Sands 1999, Extended Range 1 and 2, CAX 1999) comprised the crawl phase. The next five (Extended Range 3 and 4, JTFEX, National Training Center [NTC], Extended Range/CJTR) comprised the walk phase. The run (final) phase included the remaining exercises.

Extended Range 4-01 to Alaska was the first flight outside continental U.S. (CONUS) airspace. The flight after the stand-down was the deployment to Eglin Air Force Base, Florida, which included extensive flight time in Federal Aviation Administration (FAA)-controlled airspace. Some program participants considered the deployment to Eglin Air Force Base the most critical D&E flight test. The East Coast deployment included both ground and air vehicle deployment; several exercises over the East Coast and the first Linked Seas mission included a transatlantic flight to Portugal.

Thirteen sorties and 152.3 flight hours conducted during Phase III were for the functional checkout of air vehicle 3 (four flights), air vehicle 4 (five flights), and air vehicle 5 (four flights). An additional three sorties totaling 20.7 hours were conducted for other engineering development objectives, such as wing pressure validation.

Of the 37 missions flown in Phase III, 26 fully met their objectives, six did not meet their objectives, and five met their objectives to some degree. The D&E program concluded in May 2000 after JTFEX00. Air vehicle 4 was redeployed to EAFB from Eglin Air Force Base on June 19, 2000.[9] The next four flights were air vehicle 5's functional checkout. Flight 4 of air vehicle 5 took place on July 19, 2000, and was the last sortie in Phase III of the ACTD program.

The quick-look reports noted that many of the problems found during testing were procedural in nature, reflecting the process of learning how to operate the system and integrate it into military operations. As would be expected, performance—specifically the timeliness of imagery transmission—improved from the crawl to the walk stage, reflecting learning and updated procedures.

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[9]See the June 2000 monthly acquisition report (MAR) from the GHSPO.

The 31st Test and Evaluation Squadron

The 31st TES is a field operations unit for ACC. The ACC Director of Operations (ACC/DO) directed that the unit stand up at EAFB in the fall of 1997. The manning of the 31st TES grew to 16 to 20 full-time personnel. The 31st TES was not part of the program plan, and there was no formal process for implementing a relationship between Ryan and the 31st TES. However, Section 845 OTA was flexible enough to allow such interactions.[10] ACC understood the importance of its input to the success of the Global Hawk test program and therefore paid for 31st TES personnel by using manpower slots from the Predator program budget. The 31st TES became a core partner in the flight test program, at times providing 50 percent of mission planning capabilities and 50 percent of operations. The 31st TES added significant value in terms of configuration changes, mission planning, command-and-control officer (CCO) experience and technical orders, and an operational perspective. The unit helped shape system capabilities and operational procedures.

To address targets of opportunity, the 31st TES developed the capability for in-flight dynamic sensor retasking during operational demonstrations. Essentially, unit operators learned to "trick" the aircraft to image targets that were not part of the mission plan. As a result of the 31st TES's desire to make the system more operationally useful, its operators also learned to use the vehicle in a manner that differed from its intended design. Global Hawk was designed to be fully autonomous and, according to one operator, was expected to be used like a "wind-up toy." With the influence of the 31st TES, the system proved to be flexible and interactive.

In general, the 31st TES provided both military experience and an operational perspective and, as a result, became the Air Force expert on HAE UAV operations, supporting briefings to senior Air Force officials. The 31st TES was clearly an asset to the program and was involved to an extent more than is usually seen in traditional flight test

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[10]Agreement modifications between Ryan and the GHSPO were strictly negotiated because of the Ryan program manager's insistence on having everything precisely specified. No allowance for 31st TES participation was ever put in writing. The Ryan flight test director gave the 31st TES a role despite the disapproval of his own management.

programs. From its operational perspective, the 31st TES anticipated issues and problems and developed solutions to overcome them. Most participants agree that the 31st TES's participation was critical to the success of the Global Hawk flight test program and would probably have helped DarkStar as well.

The Global Hawk flight test experience suggests that in future ACTDs, operational users and the test community must be intimately involved in the program along with the ACTD user. The involvement of the test community must be facilitated by the Agreement. Because the involvement of the 31st was not officially recognized in this program, execution problems arose that resulted from a lack of contractual facilitation. The 31st was eventually able to gain the cooperation of the GHSPO, but significant energy had to be expended to get the required changes made.

Resource Constraints and Mission Planning

From its early stages, the D&E test program pushed hard to generate the required number of sorties. This push was likely driven by the shortened length of the overall Phase III. The cumbersome and time-consuming mission planning system required weeks or months from start to finish. The autonomous nature of the system combined with the extremely long flight duration planned for every flight made the process all the more manpower-intensive. To make matters worse, the Air Force Mission Support System (AFMSS), with which the Global Hawk mission support software must interact, was not designed to accommodate long-duration missions with hundreds of way points.

Because of the pace of the D&E program, flight test personnel were involved in five or more mission planning exercises at any given time. The pace of operations in the MUA's crawl phase was challenging given available hardware, system configuration, and personnel resources. Some participants involved in the flight test program felt that the workload required to support the exercises was more than what was considered reasonable to accomplish given the resource limitations.

Both the program's contractor personnel in San Diego and the GHSPO in Dayton were aware of the mismatch between tasking and resources. However, the contractor and government flight test personnel at EAFB adopted a "can-do" attitude and worked extremely hard. The 31st TES was overworked and stated after the fact that they had anticipated a mission planning breakdown. This eventually occurred in the form of the air vehicle 3 taxi accident, which was a direct result of the cumbersome mission planning process combined with the acceleration of the flight test program.

Air Vehicle 3 Postflight Taxi Accident

The postflight taxi accident with air vehicle 3 on December 6, 1999 (41st sortie), resulted from a mission planning failure. The mission was curtailed as a result of a problem with avionics bay temperatures. An early return to base was commanded, putting the system into contingency mode. As a consequence of air traffic congestion at EAFB, Global Hawk was forced to use a secondary contingency plan for landing and taxi. While the landing itself was uneventful, the postflight taxi commands for that particular contingency had not been validated. The mission plan had the air vehicle accelerating and turning right, as it would after takeoff. The air vehicle ended up in the desert with its nose buried in the sand.

The mission planning process failed to detect the problem. As a result of the crash, mission planning validation procedures were changed. The cumbersome mission planning process, along with an increased operating tempo and limited trained personnel, contributed to a heavy burden on Global Hawk test personnel. These were noted as contributing factors in the accident report.[11] The change to AFFTC as RTO was due entirely to the air vehicle 3 mishap and cost the program a three-month slip in an already shortened D&E phase.

Both mishaps during the test program—the destruction of air vehicle 2 and that of air vehicle 3's high-speed taxi—had two significant effects on the ACTD's core objectives. First, each mishap resulted in the loss of the EO/IR onboard sensor; hence, the operational

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[11] Accident Investigation Board report, December 6, 1999, excerpted in "Faulty Mission Preparation Cited in December Global Hawk Accident," *Inside the Air Force*, Vol. 11, No. 17, April 28, 2000, pp. 12–13.

demonstration provided no representative EO/IR imagery. Second, the timing of the losses was such that the test program never had more than two flyable aircraft at any given time and was not able to use more than a single aircraft in any demonstration.[12]

Flight Test Responsibility Change

Giving Ryan the lead for flight test activities was not an issue until the air vehicle 3 postflight taxi accident on December 6, 1999. All program participants had accepted the arrangement, and it had proved a workable one until that point. The nature of the accident was such that AFFTC no longer believed it could guarantee safety without being designated as the RTO.

When the RTO dispute arose, the SPO articulated the division of responsibilities that had been in effect throughout the flight test program: Ryan had the lead for flight test program planning and execution and was the home organization of the test director, while the SPO retained accident liability and responsibility for contingency planning and mishap investigation. AFFTC had always held test range safety responsibility. However, neither the Inspector General (IG) nor EAFB would agree to continuing under this structure. The issue was eventually resolved at the three-star level (EAFB/CC and ASC/CC). AFFTC became the RTO on February 7, 2000,[13] and immediately changed the rules on Global Hawk flight testing. Prior to the accident, AFFTC personnel had never expressed safety concerns warranting such changes.

Program participants differed significantly in their opinions on whether the substantial contractor involvement contributed to either of the Global Hawk mishaps. Ryan was not experienced as a flight test lead in an Air Force context. The contractor had a high degree of engineering competence but less experience running an operation in

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[12]This would be true for most of the D&E exercises even if resources (spare parts, trained personnel) had been increased. It is possible that had there been no resource constraints, air vehicles 1 and 4 and/or air vehicle 5 could have been flown simultaneously toward the end of Phase III.

[13]See memorandum for ASC/RA from HQ AFMC/DO (Brigadier General Wilbert D. Pearson), Subject: Responsible Test Organization Designation, Global Hawk System Test Program, February 7, 2000.

which safety and maintenance are primary concerns. Expertise in these areas lies in the flight test community. Ryan demonstrated a strength in flight test execution but a weakness in flight test planning (which the SPO needed to supplement).

Under the ACTD and OTA constructs, where contractors are given broader responsibilities, it should be required that contractors team with the test community for flight test operations. This did occur in the Global Hawk program; a strong collaborative relationship developed between Ryan and the GHSPO. The GHSPO had between two and ten personnel at each test meeting, taxi, and flight to support testing. The GHSPO had five or more personnel participating at most of the flights. For this type of approach to work, both the contractor and the government must appreciate and accommodate one another's objectives and cultures. Furthermore, the involvement of both the force provider (ACC) and the warfighter (JFCOM) is required early on to shape the system's evolution and concept of operations (CONOPS).

Despite the tension, the loss of several months of flight testing, and the need to change operational procedures, some participants felt that the RTO change did not have a significant impact on the program's ability to accomplish the ACTD objectives. Integration with other organizations (e.g., AFFTC and the FAA) was acknowledged to be somewhat more difficult. Some program participants believe that had AFFTC been the RTO, the air vehicle 3 postflight taxi mishap might have been avoided; because AFFTC is aware of lessons from past programs, it might have gone slower using a more structured process.

The change to AFFTC as RTO had undesirable consequences from JFCOM's perspective: increased bureaucracy, increased rigor required on defining missions, and new and more rules to follow.

Configuration Changes

The system's configuration evolved throughout the D&E phase as the results of continuing nonrecurring engineering activities and lessons from previous flight testing were incorporated into both hardware and software. For the most part, these changes were small and did not affect the conduct of the D&E program.

Block 1 modifications, the first significant hardware configuration changes, were incorporated onto air vehicle 4 before its delivery. These improvements included a second radio altimeter, fuel system improvements, and navigation system improvements (incorporation of the OmniSTAR DGPS navigation system as a replacement for the original LN-211 system used in Global Hawk). In this configuration, air vehicle 4 deployed to Eglin Air Force Base, with a subsequent flight to Portugal as part of the Linked Seas exercise. The flight test team had little experience with the modified air vehicle when these deployments were undertaken, causing some participants to feel that unnecessary risk was taken in deploying the modified configuration without additional testing.

Air vehicle 5 was delivered with the same Block 1 configuration. Air vehicle 3 was updated to the Block 1 configuration during its repair from the runway incident. Air vehicle 1 will also be modified to the Block 1 configuration, bringing all four surviving ACTD residual aircraft to a standard configuration.

The data generated during wing pressure validation sorties (Flights 24 and 25 of air vehicle 1) supported wing redesign on air vehicle 6 to mitigate fuel imbalance. Air vehicle 6, incorporating all the changes mentioned above, is referred to as the Block 2 configuration.

We found no evidence that the configuration changes to either the air vehicle or the ground segment caused significant problems during the ACTD flight test program. Although there were some interoperability and backward compatibility concerns during Phase III, all remaining ACTD air vehicles and ground stations had been brought to the Block 2 configuration by the end of the ACTD program.

Concept of Operations

The Global Hawk system CONOPS has been an area of disagreement between JFCOM and ACC. D&E tests were structured to demonstrate JFCOM's CONOPS, since JFCOM was the ACTD user. The December 1997 ACTD management plan directs JFCOM to validate its CONOPS through field demonstrations, which is precisely what it did. The inherently joint perspective held by JFCOM resulted in the direct dissemination of imagery from the Global Hawk MCE to multiservice exploitation systems. JFCOM found it necessary to keep vehicle control with the Air Force but advocated that real-time sensor control commands—a capability known as dynamic retasking—be allowed to alternate among field organizations as a function of geography, time, and mission/function.

In contrast, the ACC CONOPS, developed late in the ACTD to support post-ACTD planning, called for air vehicle and sensor retasking by Air Force elements only. Imagery users from the other services would have no input regarding what imagery was obtained "on the fly." ACC advocated MCE linkage to Air Force systems only, with imagery selected by the Air Force supplied to the other services secondhand. The initial ACC perspective was Air Force–centric and did not make optimal use of the capabilities already demonstrated by the nascent Global Hawk system.

JFCOM attempted to influence both requirements and CONOPS by demonstrating the feasibility and utility of its CONOPS vision. The Global Hawk system demonstrated multiple dissemination and exploitation links during the D&E exercises, including sensor-to-shooter links and dynamic retasking of the sensor by exploitation users. In other words, the JFCOM CONOPS was demonstrated. ACC was not in a position to demonstrate its CONOPS during the D&E portion of the ACTD.

The CONOPS adopted at the conclusion of the ACTD in large part drives the requirements and future development efforts for the operational system. It will shape the system as a joint asset or as an Air Force asset. ACC is responsible for generating the requirements for the post-ACTD Global Hawk system. The current system was designed to demonstrate—and did demonstrate—a different set of capabilities than those being put forth by ACC.

Military Utility Assessment

The experience of the Predator program[14] was reviewed by participants in the HAE UAV ACTD. The top-down view was that the approach worked—i.e., that Predator provides a useful capability to

[14]For a history of the Predator ACTD experience, see Michael R. Thirtle, Robert V. Johnson, and John L. Birkler, *The Predator ACTD: A Case Study for Transition Planning to the Formal Acquisition Process,* MR-899-OSD, Santa Monica: RAND, 1997.

decisionmakers. The bottom-up view was that the system is difficult to operate and sustain. These two views contrast the warfighter as a senior-level decision maker and as the field operator. In the future, both perspectives should provide input to improve the utility and operational suitability of systems.

The MUA process adopted in the Global Hawk program influenced decisions regarding the flow of imagery data and dissemination, requirements generation, and post-ACTD development activities. Different participants believe different things about the value of that information flow. At one extreme, some believed it should dominate future planning regarding requirements and EMD activities. At the other, some advocated almost ignoring that process in future planning because of perceived flaws inherent in the ACTD program structure and in system concept and configuration. This conflict has not been completely resolved. Most program participants did agree that lessons from the ACTD program should be used as a foundation upon which to build future capability.

Experience gained during the D&E exercises allowed for the identification of which performance characteristics really mattered to imagery users and to mission success. The ability to dynamically retask the sensor to take advantage of targets of opportunity turned out to have significant value to the user. This capability was not part of the original design concept but rather emerged as operating experience was gained. Similarly, the number of SAR images taken during a given sortie tended to matter less (within limits) than the quality of those images. Assessing military utility solely on the capabilities derived from the system engineering design (as AFOTEC's initial metrics were) fails to capture other important aspects of military utility that are uncovered as operational experience is gained.

Well before the final D&E sortie, program participants felt that military utility and technical feasibility had been more than adequately demonstrated. Although more flight hours would have been beneficial, it was felt that they were not necessary from a technical perspective. The reason for the high number of flight hours in the original two-year operational demonstration plan was to demonstrate reliability, maintainability, and supportability. While these system attributes were not as well understood as desired by the end of the D&E, the 13-month phase (ten months of operations plus three months of down time due to the air vehicle 3 mishap) was adequate to demonstrate the military utility of the system.

JFCOM's MUA gave Global Hawk high marks in most categories. The final MUA report reflects JFCOM's belief that the system has military utility in its current configuration and potentially greater utility as it evolves and matures.

GLOBAL HAWK SUMMARY

Table 3.1 summarizes the Global Hawk flight test program by phase and air vehicle. Air vehicle 1 was clearly the workhorse of the program, participating in both Phase II and Phase III flight tests. Air vehicles 3–5 participated only in Phase III.

Six outcomes of Global Hawk's ACTD flight test experience are either partially or wholly attributable to its novel acquisition approach:

- The mission planning process was cumbersome and time-consuming. The contractors knew at the time of the Phase II bid that significantly more funds would be required to make the mission planning system suitable for sustained operations. However, because the focus of the ACTD was on demonstrating military utility, which at the time was not well defined and did not specify timely sortie generation, a conscious decision was made to defer this investment. Had mission planning operational suitability been incorporated into a definition of

Table 3.1

Summary of the Global Hawk Flight Test Program by Phase and Air Vehicle (number of sorties/flight hours)

Phase	Air Vehicle 1	Air Vehicle 2	Air Vehicle 3	Air Vehicle 4	Air Vehicle 5	Total
II	12/102.9	9/55.1				21/158
III	13/225.4		9/121.8	11/167.8	4/39	37/554
III+					1/8.5	5/25.1
Total	25/328.3	9/55.1	9/121.8	11/167.8	5/47.5	63/737.1

utility early in the program, more funding might have been committed to it, although perhaps at the expense of other activities.

- The program lacked sufficient resources both for training personnel and for providing adequate spares. This was attributable in part to the reallocation of resources within the program to cover increased nonrecurring engineering activity, and in part to a highly constrained budget throughout the duration of the ACTD.
- The pace of the flight test program was too fast given its cumbersome mission planning process and limited resources. Test personnel were clearly overburdened, which appears to have been a contributing factor in the air vehicle 3 taxi mishap.
- The designation of contractors as the lead for flight test direction, planning, and execution could have resulted in a failed program. Contractors may not have the necessary capabilities, experience, and perspective (culture) to run all aspects of a military test program. The test and operational communities thus took on a large portion of the planning and execution of the flight test program. Their assistance was essential to the accomplishments of the program.
- The differences in perspective between the ACTD and post-ACTD user communities regarding the CONOPS proved to be a serious impediment to the program's transition into the Major Defense Acquisition Program (MDAP) process. The initial CONOPS was generated by the DARPA JPO and was then modified and expanded by JFCOM as part of its responsibility as a designated ACTD user. ACC's CONOPS is similar to current systems in terms of its access to sensor retasking and dissemination pathways; ACC believes that this is what the CINCs want. JFCOM's CONOPS takes advantage of advances in communications and processing technology and adopts a joint orientation. The ACTD D&E phase demonstrated the JFCOM CONOPS; ACC has not demonstrated its CONOPS with respect to Global Hawk.
- Differences between the ACTD and post-ACTD user in operational requirements definition are also inhibiting the program's transition to an MDAP. The extent to which the capabilities of the ACTD configuration—demonstrated through testing—should

determine the requirements for a post-ACTD system is the underlying issue. The spiral development concept planned for use in post-ACTD development implies that requirements will evolve along with the system's configuration and block upgrades. As a result of this process, early configurations will not have the full capability that ACC, the force provider, desires. Initial drafts of the ORD that is required for all MDAPs were not wholly reflective of the system's demonstrated capabilities and subsequent evolution based on known shortfalls.

Many Global Hawk performance parameters are close to the predicted goals, but some fall short in several significant areas. In particular, a 16 percent increase in empty weight and lower-than-predicted aerodynamic performance resulted in a 20 percent endurance shortfall (32 hours versus 40 hours) and a 7.7 percent shortfall in mission cruise altitude (60 kft versus 65 kft).[15] The ACTD program demonstrated the system's capability for autonomous high-altitude endurance flight. Most communications and data links were demonstrated sufficiently. The SAR sensor can provide high-quality imagery. However, the CGS did not demonstrate control of multiple vehicles; nor was the EO/IR sensor characterized sufficiently.

The time to first flight of Global Hawk was somewhat typical, but the time from first flight to first operational use was extraordinarily short. The system demonstrated operational utility in its current configuration and could be used given contractor support in an operational theater of war.

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[15]The original DARPA mission profile shows a 3000-nm ingress, a 24-hour on-station segment at 65 kft, and a 3000-nm egress. It is this on-station "cruise" segment that Global Hawk cannot achieve. Global Hawk can achieve an altitude of 65,000 ft for shorter periods of time under certain environmental and weight-related (e.g., fuel remaining) conditions.