Chapter Two

OVERVIEW OF THE HAE UAV ACTD FLIGHT TEST PROGRAM

EVOLUTION OF THE INITIAL PLAN AND UNDERLYING PHILOSOPHY

The December 15, 1994, HAE UAV ACTD management plan, one of the earliest documents providing guidance for program execution, addressed testing in only the broadest terms. Flight tests were to be conducted as part of Phases II (development) and III (D&E). Phase II would include a 12-month test program using two engineering development UAV models and an engineering test model CGS.[1] Phase III, a 24-month field demonstration involving the participation of operational users, was to use field demonstration model UAVs: eight conventional HAE UAVs (Global Hawk), up to eight LO HAE UAVs (DarkStar) if funding permitted, and two additional CGSs. Phase III was to include the combined testing of the conventional and LO vehicles during field demonstrations with operational forces. The Phase II tests for both air vehicles were intended to be conducted by the contractors. Phase III testing included participation in DoD training exercises, as distinct from traditional operational testing.

The expectation in the December 1994 management plan was clearly that all air vehicles, both conventional and LO, would be essentially identical, leading to a direct and orderly transition into production. The plan stated that at the completion of the ACTD, a residual opera-

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[1]See Defense Adanced Research Projects Agency, *HAE UAV ACTD Management Plan*, Arlington, VA, December 15, 1994, p. 20, Figure 2.

tional capability would be available that would consist of ten conventional HAE UAVs (two engineering and eight field models), all with payloads; three CGSs (one engineering and two field demonstration models); two LO HAE UAV engineering models; and up to eight LO field demonstration models. Additionally, there would be 200 trained personnel (military and contractor).[2] DARO, the sponsoring agency, would fund the program through the completion of Phase III. The Air Force, as the lead agency, was expected to program operations and support (O&S) funds for the maintenance and operation of the residual systems.

This early management plan did not specify the number of flight hours expected from either Phase II or Phase III. It did, however, make clear the importance of the flight test program in the context of the ACTD construct (a full three years was planned, representing more than half the ACTD schedule). The plan also introduced the notion of contractor responsibility for the flight test program as well as early user participation through the field test portion of the flight test program.

The initial Master Test Plan for Global Hawk, developed by the air vehicle contractor, Teledyne Ryan Aeronautical (Ryan), was released on March 30, 1995, during Phase I of the program. A revised test plan was issued in November 1995, early in Phase II.[3] This document, which incorporated IPT comments and formed the basis of the Phase II flight test program, laid the groundwork for the roles and responsibilities of government and contractor while also setting the procedures for the conduct of flight tests. The government was invited to participate at all IPT levels, but the contractor was to be in charge. All tests would follow a previously approved test plan ranging in scope from engineering design validation to complex flight tests requiring interagency (FAA, test range) coordination.

The primary objective of Phase II testing was to measure system technical performance against the characteristics of the contractor's written system specification. Technical performance measures

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[2]Op. cit., p. 20. Assumes no loss of assets during the test program.

[3]Teledyne Ryan Aeronautical, *Master Test Plan for the Tier II Plus High Altitude Endurance (HAE) Unmanned Air Vehicle*, San Diego, CA, Report No. TRA-367-5000-67-R-001A, November 17, 1995.

(TPMs) and system maturity matrix (SMM) goals were identified and cross-referenced to the preliminary system specification. The TPMs were related to the technical and payload incentives embodied in Attachment 5 of the Ryan Agreement. The test plan included ground-based system and subsystem tests required to demonstrate flight readiness. Up to seven airworthiness flights and up to nine payload flights were planned. For each flight, both primary and secondary objectives were identified.

The small number of flights in the Global Hawk test plan (16) was facilitated by the relatively small area of the flight envelope inherent in HAE aircraft. The elapsed time/vehicle speed/altitude mission profile for every test flight would be similar with the exception of time at cruise. The primary stress on the air vehicle and sensor payload derives from increasing dwell times at high altitude. Thus, endurance and sensor performance are tested at various altitudes.

The December 30, 1997, HAE UAV ACTD management plan (version 7) gave somewhat more attention to flight test planning.[4] Phase II engineering tests conducted separately for both Global Hawk and DarkStar were to begin in the middle of FY 1997 and were to last through the end of FY 1998. The Air Force Flight Test Center (AFFTC) was to handle airspace coordination for Global Hawk. Phase II activities called out in the plan included:

- Defining user segments to facilitate early developer and user integration;
- Establishing system baselines and characterization;
- Developing planning tools and employment techniques for the user; and
- Publishing the HAE UAV ACTD assessment operations plan (OPLAN), which establishes user military utility assessment (MUA) methods and objectives.

[4]Note that all management plans through the December 1997 version were written by the DARPA joint program office. The last (version 7) was the one that transitioned to the Air Force; no update was approved prior to the October 1998 management transition.

Global Hawk engineering development tests would include seven airworthiness flights and nine payload flights over a 12-month period. The only listed criterion for transition from Phase II to Phase III was approval from the HAE UAV Oversight Group.

Phase III D&E testing was to begin in the last quarter of FY 1998 and was to continue through the end of FY 1999. Exercises were to be identified by asking the commanders in chief (CINCs) for their joint mission-essential task lists (JMETLs), whose purpose was to define tasks in which HAE UAV participation could make a difference. The number of exercises would be chosen on the basis of the number needed to sufficiently characterize the system's utility. Phase III was intended to be a combined testing of DarkStar and Global Hawk, moving from scripted demonstrations to more complex participation in scheduled exercises. Contractor maintenance and operational support was to be used. The United States Atlantic Command (USACOM) was to plan and execute the Phase III demonstrations. The results were intended to inform the then-planned force mix and MUA decisions at the completion of the ACTD.

By December 1997, cost increases in the program had reduced the number of available vehicles for Phase III D&E. The management plan stated that up to eight Global Hawk and/or DarkStar air vehicles and two CGSs would support user demonstrations.

Planning for Phase III D&E testing was also initiated in 1995. The ACTD office in USACOM stood up in February 1996 with roughly ten programs, one of which was an HAE UAV. USACOM began formally planning for the HAE UAV MUA in May 1996. Toward the end of Phase III, the Joint Forces Command (JFCOM) had six people working the program, but most of the work was done by two individuals, one of whom was the designated operational manager (OM) in the HAE UAV ACTD program structure.[5]

The program office defined an MUA algorithm in late 1995. The algorithm was presented in charts at the monthly Home Day meeting in January 1996. Nominal values were calculated at design reviews in support of the algorithm. The MUA algorithm shown below results in a single-point estimate.

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[5]Colonel John Wellman, U.S. Air Force, and Walt Harris.

> MU = f(area coverage × no. of targets/day × no. of UAVs required × targeting accuracy × timeliness × image quality × flexibility × (threat, CONOPS, mission planning, survivability suite).

Either JFCOM rejected the algorithmic approach or both the joint program office (JPO) and JFCOM had abandoned it by the time detailed planning for D&E began. As a result, the algorithm appears to have played no role in the assessment. In any case, a single-point multidimensional quantitative estimate is not an appropriate indicator of military utility for a system as complex and capable as the HAE UAV. However, the algorithm does suggest the types of metrics that could be used in the MUA, although their relative importance was not indicated.

USACOM/JFCOM originally hired the Defense Evaluation Support Activity (DESA) to help design and execute the D&E phase. Shortly thereafter, DESA became Detachment 1 of the Air Force Operational Test and Evaluation Center (AFOTEC) as a result of a reorganization. JFCOM was somewhat concerned that this organizational change would result in the incorporation of Air Force biases, but Detachment 1 remained a separate organization within AFOTEC and maintained its objectivity. In collecting and organizing test data, Detachment 1 did use many of the same formats and styles as the rest of AFOTEC. Detachment 1 would collect the data and write the quick-look reports and summary reports. JFCOM would write the final MUA defining the HAE UAV's value added to the D&E exercises. The JFCOM CINC had final approval authority for the MUA. This CINC was involved in and supportive of the HAE UAV ACTD program. Beyond the specific approach laid out in the integrated assessment plan (IAP), he set up a strict criterion for determining military utility: to *prove* that the HAE UAV makes a difference in operations.

JFCOM/AFOTEC initially stated that approximately 2000 flight hours would be needed to demonstrate military utility. At the expected flight-hour accumulation rate, this roughly translates into a three-year flight test program. The number of flight hours required was driven by operational suitability concerns. Given the shortened D&E in which an unknown number of flight hours would be accumulated, a "crawl-walk-jog-run" pattern was eventually agreed on in which the pace of flight test activity was to increase over time.

The D&E phase was designed from its inception to collect as much traditional development test/operational test (DT/OT) data as possible to facilitate a tailored and streamlined post-ACTD development program. In early 1996, when the D&E plan was first put together, JFCOM asked AFOTEC to identify the type of information needed in a traditional DT/OT flight test program as well as to estimate approximately how many flight hours that program has traditionally taken. The D&E phase was structured on the basis of that input, recognizing that all such information could not be collected. The plan included 1200 hours of flight test, derived from Air Force "maturity" statistics. Establishing the system's reliability, maintainability, and supportability characteristics constituted the primary driver.

The November 1995 Master Test Plan for Global Hawk also briefly discussed a notional Phase III field demonstration program. It noted the participation of the Tier III– and added that system capabilities should be expected to evolve as the results of each flight test are used to enhance system performance. The assessment of effectiveness and suitability was identified as the primary Phase III objective and criterion for military utility. Effectiveness was defined as including long operational range, extended endurance, interface with existing command, control, communications, computers, and intelligence (C4I) architecture, high-resolution sensors, and geolocation accuracy. Suitability was said to include flexibility in basing, transportability, safety, availability, maintainability, and supportability. The last three criteria are particularly notable for an ACTD. Phase II assets may be used in support of demonstration activities as needed. The stated objective was to demonstrate military utility to the user while simultaneously demonstrating system performance characteristics. Demonstration tests would be formally planned with mission cards, go/no-go criteria, support plans, and the like. The notional beginning of field demonstrations was January 1998. The initial pace was four 24-hour flights per month, increasing to 20 flights per month by the sixth month. Operations were expected to transition from a "training condition" to a "deployable condition." The simultaneous deployment of a full system that included four Tier II+ vehicles, two Tier III– vehicles, one ground segment, and a spares kit, together with continued operations of 250 flight hours per month from the main operating base (MOB), was envisioned.

After the completion of the 16 engineering flight tests, cumulative flight hours were expected to rapidly increase as additional assets became available (e.g., eight additional Tier II+ air vehicles and two additional CGSs delivered during the 24-month Phase III). Table 2.1 shows the expected buildup of flight hours for the Tier II+ by quarter. By the end of 1998, eight UAVs were expected to be flying; all ten were expected to be flying by the end of the first quarter of 1999 (representing a delivery rate of two air vehicles per quarter beginning in the second quarter of 1998).

The DARPA JPO's review of the contractor's initial test plan was somewhat critical of that plan in terms of the detail made available, the lack of a master test matrix, and the relationship of Simulation and Integration Laboratory (SIL)/nonflight tests to the flight test program.[6] It would appear that these problems were adequately addressed in subsequent plans.

The test plan states the expectation that live fire testing will not be required for the HAE UAV ACTD program based on a September 19, 1995, letter from the Deputy Director of Live Fire Testing.

Table 2.1

Early Notional Phase III Field Demonstration Plan

	1998 (quarter)				1999 (quarter)			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Flights per quarter	12	24	60	60	60	60	60	60
Flight hours per quarter	300	600	1500	1500	1500	1500	1500	1500
Cumulative flight hours (Phase III)	300	900	2400	3900	5400	6900	8400	9900

SOURCE: Teledyne Ryan Aeronautical, *Master Test Plan for the Tier II Plus High Altitude Endurance (HAE) Unmanned Aerial Vehicle,* San Diego, CA, Report No. TRA-367-5000-67-R-001A, November 17, 1995.

[6]See Home Day charts, August 1996.

In general, the HAE UAV ACTD test plan appeared similar to that of a traditional program in its use of formal test plans, performance matrices, and readiness reviews and in its linking of ground and flight testing. The key difference lay in the fact that test planning and execution were to be led by the contractor. With only 16 flights planned, the Phase II engineering test plan seemed rather thin, but this is understandable given the limited flight envelope of HAE aircraft. By contrast, the Phase III D&E phase laid out early in the program seemed somewhat ambitious. Overall, the plan appeared to be unrealistic, especially given the technical unknowns associated with a system that represented such a fundamental departure from prior experience.

FLIGHT TEST PROGRAM EXECUTION

The first air vehicle to fly in the HAE UAV ACTD program was DarkStar, whose first flight took place on March 29, 1996. This air vehicle was destroyed on April 22, 1996, as it was taking off for its second flight.[7] The HAE UAV ACTD flight test program resumed activity on February 28, 1998, some 22 months later, with the first flight of Global Hawk. DarkStar resumed flights with air vehicle 2 on June 29, 1998, some 26 months after the loss of the first DarkStar. The last formal ACTD flight test, conducted on July 19, 2000, consisted of a functional checkout of Global Hawk air vehicle 5.

Excluding the first two DarkStar flights, the flight test program for both air vehicles appears to have been fairly cautious. A pattern of learning—test, analyze, fix, test—is clearly evident for both Global Hawk and DarkStar.

The flight test program also represented a steady progression in learning, particularly for Global Hawk. Each flight generated more confidence in both air vehicle and ground systems. Minor anomalies occurred but were resolved. Overall, the flight test program was characterized by a steady, planned envelope expansion and capability demonstration for both engineering and D&E elements of the

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[7]See Drezner, Sommer, and Leonard, *Innovative Management in the DARPA High Altitude Endurance Unmanned Aerial Vehicle Program,* 1999, for more detail on the crash, its causes, and its consequences.

flight test. Flash reports and quick-look reports[8] were written for all flights; these constituted after-action reports for each sortie and supported a continuous MUA process. The program had no formal performance requirements, but information continually emerging from the flight test program was intended to support operational requirements document (ORD) development.

Summary information on the ACTD flight test program is provided in Table 2.2. Not surprisingly, neither DarkStar's nor Global Hawk's flight test program was executed as originally planned.

DarkStar

The first flight of DarkStar air vehicle 1 was characterized by significant anomalies. These were not sufficiently resolved by the time of the second flight on April 22, 1996, resulting in the vehicle's destruction on takeoff.

DarkStar air vehicle 2 first flew 26 months later. As Figure 2.1 shows, DarkStar flight testing with air vehicle 2 lasted for six months, a period in which only six hours of flight time were accumulated.

Table 2.2

Summary Flight Information for ACTD Air Vehicles[a]

Air Vehicle	First Flight Date	Total Cumulative Flight Hours
DarkStar 1	March 29, 1996	0.75
DarkStar 2	June 29, 1998	6.0
DarkStar 3	n.a.	n.a.
Global Hawk 1	February 28, 1998	328.3
Global Hawk 2	November 20, 1998	55.1
Global Hawk 3	August 12, 1999	121.8
Global Hawk 4	March 24, 2000	167.8
Global Hawk 5	June 30, 2000	64.1

[a]Data as of September 14, 2000.

[8]Flash reports were brief summaries written and distributed immediately following each sortie. Quick-look reports provided more detailed descriptions of each flight test, assessed the extent to which flight test objectives had been achieved, and documented possible problems and anomalies.

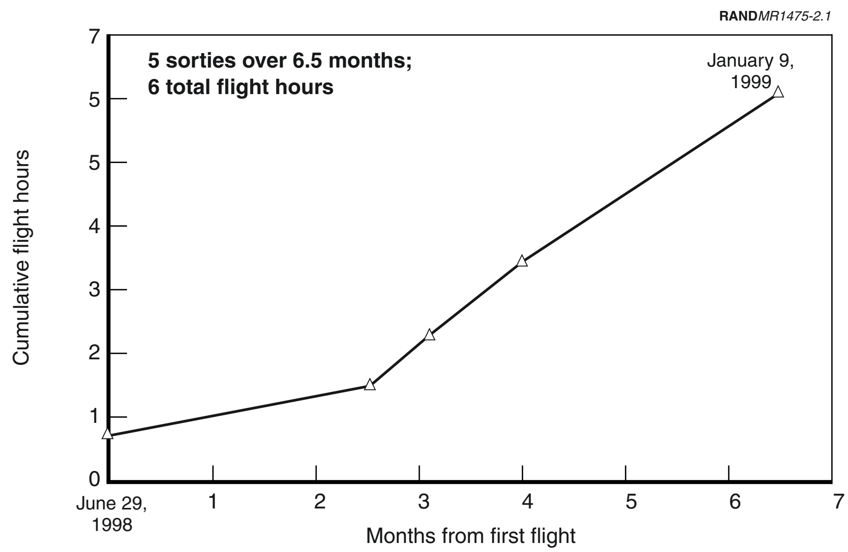

Figure 2.1—DarkStar Air Vehicle 2 ACTD Flight Test Program

DarkStar was terminated a day before its planned seventh flight and never entered Phase III D&E. An important concern is whether the shortened flight test program yielded useful results in the form of either technical characteristics relating to air vehicle configuration or lessons regarding operating procedures.

Global Hawk

The first flight of Global Hawk occurred on February 28, 1998 (Figure 2.2). Phase II engineering flight testing included the first 21 sorties. Phase III flight testing included sorties 22 through 58.[9] The Phase III flight test program included D&E sorties associated with a specific military exercise as well as some additional functional checkout and follow-on engineering flights. Post–Phase III flight testing, which in-

[9]The flash report for Flight 58, air vehicle 5, sortie 4 specifically states that this was the final Phase III sortie.

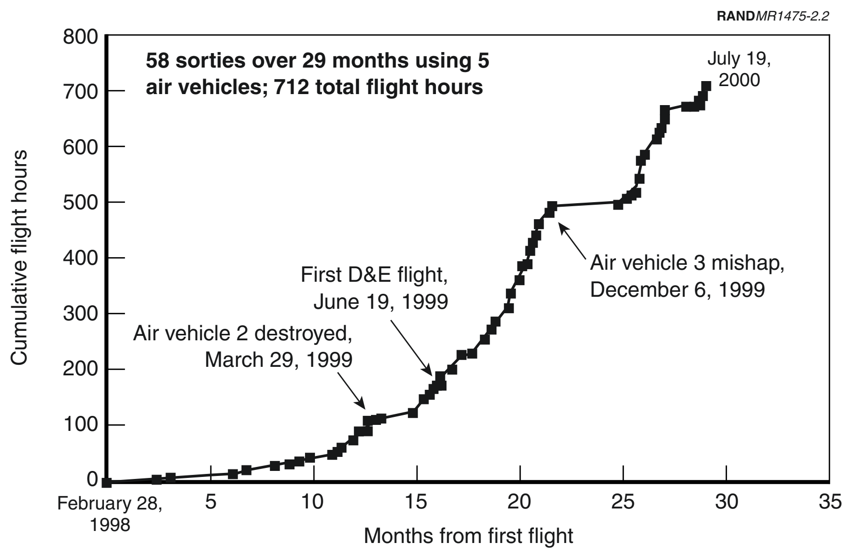

Figure 2.2—Global Hawk ACTD Flight Test Program

cluded Flight 59 and subsequent (not included in Figure 2.2), supported both preparation for the Australian deployment and another D&E exercise (Joint Expeditionary Forces Experiment [JEFX]). No more than two air vehicles participated in the ACTD flight test program at any one time because air vehicle 2 was destroyed several months before air vehicle 3 became operational and because the air vehicle 3 postflight taxi mishap occurred prior to the first flight of air vehicle 4. Global Hawk's 29-month ACTD test program reflects a clear pattern of building confidence in the system; the pace of flight testing increased significantly as the program proceeded.

Common Ground Segment

Both DarkStar and Global Hawk were designed with distinct ground segments consisting of a launch element and a mission element. In early 1995, planning for the CGS was initiated. The CGS essentially incorporated DarkStar functionality into the Global Hawk ground segment.

The CGS[10] had two primary components: the launch and recovery element (LRE) and the mission control element (MCE). The former does what one might expect given its name: it handles the air vehicle's taxi, takeoff, and climb-out at the beginning of a flight as well as its descent, approach, landing, and taxi at the end of a flight. The latter takes control of the aircraft during its climb to mission altitude; controls the aircraft and tasks the sensors through its mission; and flies the aircraft toward its landing site until the LRE takes over in preparation for landing.

MCE 1 was delivered to Ryan on October 1997. LRE 1 was delivered to Ryan on November 1996 for air vehicle integration, and was deployed to Edwards Air Force Base (EAFB) in October 1997 in support of Phase II flight tests. LRE 2 (considered part of CGS 1) was delivered to Boeing in November 1998 for DarkStar integration but was returned to Raytheon in February 1999, where it was retrofit to a Global Hawk–only configuration and delivered to Ryan in June 1999. MCE 2 was delivered to Ryan in September 1999. MCE 1 was returned to Raytheon in December 1999 for an upgrade and was then returned to Ryan in March 2000. LRE 3 (which was considered part of CGS 2) was delivered to Ryan in November 1999. LRE 1 was returned to Raytheon for an upgrade in February 2000 and was returned in June 2000. All LREs and MCEs supported Phase III testing at some point.

CGS performance was clearly a major concern during flight test, as much of the HAE UAV's capability was embodied in the ground segment. The performance of both the LRE and the MCE appeared satisfactory during both Phase II and Phase III testing; we uncovered no evidence of significant performance problems. However, ground segment–related issues pertaining to operational procedures, to the roles and responsibilities of functions within the CGS system, and to the time-consuming and difficult mission planning process did arise during test. Operational issues were resolved as more experience was gained with the system. The mission planning system is the target of major improvements in post-ACTD plans.

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[10]Now simply known as the ground segment.

The CGS was tested in its Global Hawk–only configuration but did not play a role in the shortened DarkStar flight test program, as DarkStar used its own uniquely developed ground segment. The CGS was never fully tested during Global Hawk's flight test program. Following DarkStar's cancellation, there was no opportunity to determine whether the "common" aspect of the CGS functioned adequately. Owing to the lack of trained personnel and spares that allowed just one air vehicle in flight at any one time, the CGS never demonstrated the ability to control multiple air vehicles simultaneously.

POLICY IMPLICATIONS

From an acquisition policy perspective, there are three important aspects of the HAE UAV ACTD flight test program:

1. Contractors were given significantly increased responsibility and had the lead for flight test planning and execution.
2. Development testing and operational testing were concurrent during the ACTD.
3. The program was characterized by early user involvement in planning and executing operational demonstrations prior to the completion of development testing.

The application of Section 845 OTA and the delegation of design and management authority to the contractors resulted in the contractors' designation as the lead for test planning and execution. In traditional programs, the flight test center associated with the test range is usually designated the responsible test organization (RTO) for both technical and safety elements. In this case, the RTO's responsibilities were shared between the contractors, the program office, and AFFTC. This increased contractor involvement changed the institutional dynamic of the flight test program. Some participants claim that these changes resulted in a more targeted and flexible flight test program with faster decisionmaking and approval. Other participants, however, suggest that giving the contractor the execution lead contributed at least indirectly to the various mishaps that affected the program. All participants agree that contractors generally lack the operational perspective to successfully and safely run a flight test program and thus require support from on-site operators and from the test center.

The ACTD user (USACOM/JFCOM) had significant input into flight test planning and execution, particularly in the D&E portion. Without JFCOM's involvement, supporting exercises would have been administratively impossible for the JPO to accomplish as the JPO had neither the authority nor the experience to define and manage its participation in joint military exercises. Representatives of the force provider—i.e., the 31st Test and Evaluation Squadron (TES) from the Air Combat Command (ACC)—were major participants in the flight test program, although they were not included in the plan. Such user participation in early testing, although not common in traditional acquisition approaches, benefited all participants in the HAE UAV ACTD program. In addition, Phase III D&E included combined DT/OT on almost every flight. This is highly unusual early in a program.

Two key acquisition policy–related issues arise with respect to the Global Hawk system flight test program. The first lies in determining whether the flight test program was sufficient to satisfy the objectives of the ACTD. Put another way, did the flight test program generate sufficient information to adequately characterize the system's effectiveness, suitability, and interoperability? Flight testing is somewhat different today than in the past. The measure of merit for a program no longer consists of the number of sorties generated or cumulative flight hours; instead, it pivots on whether adequate information was collected. Considerably more information is collected during each sortie today than in the past.[11]

Second, to what extent can the accomplishments of the ACTD flight test program be used to tailor and shorten post-ACTD flight test activities? In particular, to what extent can Global Hawk's ACTD flight test experience satisfy developmental and operational testing requirements mandated for engineering and manufacturing development (EMD) programs?

The remainder of this document addresses these questions.

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[11]See William B. Scott, "F-22 Flight Tests Paced by Aircraft Availability," *Aviation Week & Space Technology*, October 16, 2000, pp. 53–54.