HAE UAV efforts do not involve simply building a glorified model airplane or drone, as some who view UAVs as “low tech” compared to manned aircraft might imagine. On the contrary, the Global Hawk and DarkStar programs are in many respects at least as complex and challenging as typical manned aircraft developments. Each of the two HAE UAV programs involved the development of multiple system segments: an air vehicle, sensor payloads, and ground segments (one unique to each platform plus the CGS). Most major defense programs develop only one of these basic elements: the air vehicle, sensors or some other payload, or a ground station.

For purposes of comparison, the Global Hawk and DarkStar development efforts were considered roughly equivalent to those of contemporary manned military aircraft programs that created all-new air vehicle designs. For the most part, it was not possible to compare the costs of the two HAE UAV development efforts to those of recent or historical UAV programs, as we found no unclassified or declassified UAV program with both sufficient available data and sufficient complexity and technological challenge to be appropriate for cost comparison to the Global Hawk and DarkStar HAE UAVs. In our schedule comparison, we do include other UAV programs along with appropriate manned programs. In this area, we again believe that the latter are the more appropriate comparative systems.
THE SYSTEM CONCEPT AND ACTD CONSTRUCT DICTATED A UNIQUE FLIGHT TEST PROGRAM

The uniqueness of flight testing an autonomous HAE UAV complicates comparisons. The development of an autonomous UAV requires an enhanced understanding of the system earlier in testing than what is required for a manned or remotely piloted vehicle system. Manned aircraft have the benefit of the pilot’s ability to identify problems through the direct feel of the air vehicle, and his or her reactions can mitigate problems during flight testing. A remotely piloted vehicle has a human in the loop if not onboard, thus offering the advantage of real-time human input. HAE UAV flight testing benefited neither from real-time human input nor from real-time human feedback from the air vehicle.

Flight test comparisons are also complicated by differences in the area and composition of flight envelopes (speed, altitude, maneuverability) for different aircraft types. The high-altitude and long-range mission profile of the HAE UAVs is specifically and narrowly defined, resulting in an air vehicle flight envelope with a very small area. Other aircraft types have missions that rely on great aerodynamic flexibility, dictating the use of larger-area flight envelopes that must be explored during flight test.

Figure 3.1 presents a rough comparison of aircraft flight test programs. Global Hawk’s flight test experience is compared with the flight test experience of several fighter aircraft during their advanced technology demonstration and EMD development phases. We observe a very different pattern of flight hour accumulation over time in the Global Hawk ACTD. Fighter aircraft tend to accumulate hours much faster as multiple aircraft fly multiple short sorties each month. Global Hawk had only two aircraft in flight-ready status at any one time and generally flew no more than three long-duration sorties per month.

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1 Data on the U-2 (the system most similar to the HAE UAVs) flight test program were unavailable.
Figure 3.1—Comparison of Aircraft Flight Test Programs

As shown in Table 3.1, a comparison of the Global Hawk ACTD to prototype programs provides a different perspective.\(^2\) The AX program involving two pairs of attack prototype aircraft included a very short, seven-month flight test program. The first five months were conducted by the contractors, and in the next two a formal competitive fly-off using Air Force pilots was undertaken. In the first five months, the YA-9 accumulated 162 hours using two aircraft and an additional 145.5 hours (in 123 sorties) in the two-month competitive evaluation. The competing YA-10 accumulated 190 hours in the first

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Table 3.1
Prototype Program Flight Test Comparison

<table>
<thead>
<tr>
<th>Program</th>
<th>Testing Type</th>
<th>Duration (months)</th>
<th>Flight Hours</th>
<th>Sorties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Hawk</td>
<td>Engineering</td>
<td>6</td>
<td>20.5</td>
<td>5</td>
</tr>
<tr>
<td>YA-9</td>
<td>Engineering</td>
<td>5</td>
<td>162.0</td>
<td>N/A</td>
</tr>
<tr>
<td>YA-9</td>
<td>Demonstration</td>
<td>2</td>
<td>145.5</td>
<td>123</td>
</tr>
<tr>
<td>YA-10</td>
<td>Engineering</td>
<td>5</td>
<td>190.0</td>
<td>N/A</td>
</tr>
<tr>
<td>YA-10</td>
<td>Demonstration</td>
<td>2</td>
<td>138.5</td>
<td>87</td>
</tr>
<tr>
<td>YF-16 Program</td>
<td>Program total</td>
<td>11</td>
<td>450.0</td>
<td>320</td>
</tr>
<tr>
<td>YF-17 Program</td>
<td>Program total</td>
<td>7</td>
<td>350.0</td>
<td>230</td>
</tr>
</tbody>
</table>

five months with its two aircraft and 138.5 hours (87 sorties) in the
two-month fly-off. The YA-10s were then used for 16 months during
data/evaluation (FSE) for follow-on development test and
evaluation (DT&E) and initial operational test and evaluation
(IOT&E) prior to the low-rate production decision. In contrast,
Global Hawk accumulated 20.5 flight hours in five sorties in the first
six months of its flight test.

The Lightweight Fighter (LWF) program of the early 1970s was a
highly streamlined effort involving two pairs of prototype fighter air-
craft. In 11 months in 1974, the YF-16 accumulated approximately
450 hours in 320 sorties. The YF-17 flew 230 sorties and accumulated
approximately 350 hours in a seven-month period that same year.
Clearly the pace of the LWF program flight test was much faster than
that of Global Hawk. This is due in part to Global Hawk’s system
type—a large autonomous UAV. Global Hawk requires much more
preparation for each mission, specifically in the area of mission
planning.

Both competitive prototype flight test programs described above had
informal MUAs through the participation of operationally oriented
test pilots. The introduction of JFCOM in the Global Hawk ACTD as
the architect of the D&E phase, with a focus on the formal demon-
stration of UAV as a joint warfighting asset, differed from the “ACC-
equivalent” user approach involved in these comparative programs
from the 1970s.

In general, traditional fighter aircraft EMD flight test programs fly
more sorties per month and accumulate more flight hours than did
Comparison to Other Programs

Global Hawk during its ACTD. The main explanation for this difference is the vastly larger flight envelope for fighter systems and the need to satisfy myriad requirements, as is traditionally the approach in an MDAP-compliant EMD effort.

MORE WAS ACCOMPLISHED AT A SOMEWHAT LESSER COST

Development activity through the end of the ACTD and into follow-on development efforts was examined in two segments: the early portion embodied in the ACTD’s Phase II, which involved the design and build of the first two air vehicles, and the remainder of the ACTD along with proposed follow-on development activity. The former applies to both the Global Hawk and DarkStar programs; the latter applies only to the Global Hawk program. Analysis of DarkStar beyond its Phase II is not possible, as its Phase IIB—the building of follow-on aircraft—was not completed.

Figure 3.2 compares the costs of the two HAE UAV ACTD Phase II efforts to those of selected manned military aircraft demonstration/validation (dem/val), prototype and technology demonstration programs of the past 30 years. The systems in Figure 3.2 represent experimental fighter, attack, cargo, and reconnaissance aircraft. Roughly similar basic activities are found in all of these programs regardless of whether the air vehicle was intended to evolve into an operational system.

For the six programs showing two segments to their cost bar, the lower segment represents the program’s cost excluding flight test activity, which is accounted for in the upper segment. The OTA contractual arrangements in the Global Hawk and DarkStar programs made it difficult to break out flight test costs from those of other activities during Phase II; thus, a single-segment bar is shown for total cost of the phase. Tacit Blue data were available only in aggregate;

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3The Advanced Tactical Fighter dem/val program is not shown. The cost of each of the YF-22 and YF-23 programs was over $2 billion in TY dollars (when prime and subcontractor investments are included).

4The Have Blue technology demonstration program informed the development of the F-117, which is essentially an attack aircraft.
hence the single bar. The costs of flight testing in the YF-16 and YF-17 prototype programs did not come out of these programs’ budgets and were not separately accounted for. As a result, these flight test costs are not available in the historical record and are not included in Figure 3.2.5

Total expenditures in the programs shown in Figure 3.2, escalated to FY 2001 dollars, range from a low of less than $200 million to a high of more than $500 million. The average costs for the design-and-build portion and for the flight test portion of the historical programs for which such costs can be determined are $275 million and $92 million, respectively.6 By our calculations, Global Hawk Phase II cost $238 million paid to contractors plus allocated government costs of roughly $40 million. DarkStar cost $220 million in payments to contractors plus allocated government costs of some $37 million.7 Converted to FY 2001 dollars, the Global Hawk and DarkStar totals come to $295 million and $273 million, respectively.

Each program shown in Figure 3.2 accomplished a unique set of activities. Our opinion is that the best comparative programs for DarkStar are Have Blue and Tacit Blue and for Global Hawk the LWF prototypes. Given the activity content of Phase II and the pending operational demonstration for the HAE UAVs at the conclusion of that phase, we believe that the developmental maturity of the HAE UAVs at the end of Phase II of the ACTD was higher than that of any comparative program listed in Figure 3.2.


6The average for the design-and-build portion is calculated from these costs in the X-31, X-29, YC-15, YC-14, YF-17, YF-16, Have Blue, and XFV-12 programs. The average for the flight test portion is calculated from this cost in the X-31, X-29, YC-15, YC-14, Have Blue, and XFV-12 programs.

7See Leonard and Drezner, Innovative Development: Global Hawk and DarkStar in the HAE UAV ACTD—Program Description and Comparative Analysis, 2001, for a full explanation of costs. As of January 1999, total government costs during the ACTD were estimated at $138 million. Global Hawk Phase II accounted for 29 percent of all payments to contractors in the ACTD; thus, that percentage of government costs is allocated to the effort. For DarkStar, the figure is 27 percent.
The final cost of DarkStar Phase II was roughly what one would have expected given the costs and accomplishments of comparable historical programs such as Have Blue and Tacit Blue. We found that the Global Hawk Phase II effort compared favorably to the LWF prototypes once each was adjusted for known definitional differences in their estimates. This is a favorable outcome given that conventional wisdom views the LWF prototype program as one of the most successful prototype programs in Air Force history.

A different and perhaps more important comparative metric lies in estimating the value of the overall acquisition strategy in reducing future development costs. We define the Global Hawk equivalent EMD program as ACTD Phases IIB and III; Phases IIC and the pre-EMD, which bridge the ACTD to the formal EMD; and the planned Spirals 1 and 2 in EMD. The cumulative costs of these six phases are compared to EMD expenditures in the F-16A/B, F/A-18A/B, and F-117A programs. The projected cost of the Global Hawk–equivalent EMD is about $1.1 billion in FY 2001 dollars. This is only slightly more than half the inflation-adjusted EMD costs in the least
expensive of the comparison programs, the F-16, and slightly more than one-third more than the inflation-adjusted expense of the most appropriate EMD comparison program, the F-117. F/A-18A/B EMD costs were the highest of all the other programs.

A large band of uncertainty surrounds the future of Global Hawk development expenditures. However, after realistic upper and lower bounds for Global Hawk’s equivalent EMD figure have been defined, its cost will be considerably less than what one might expect given historical programs of roughly similar technological challenge and system complexity.

**MILITARY UTILITY WAS DEMONSTRATED MORE QUICKLY**

The Global Hawk ACTD concluded with a system more developmentally mature than what is typical at the conclusion of a prototype, an advanced technology demonstrator, or a dem/val program. At the same time, the Global Hawk ACTD did not attain the system maturity typically seen at the conclusion of a traditional EMD program.

Figure 3.3 compares in some detail the overall schedules for selected programs.\(^8\) The time to the first flight of the prototype (✩) and the time to the first flight of an EMD test aircraft (оборот) are indicated.\(^9\) The length of time from program start to EMD initiation for Global Hawk and DarkStar\(^10\) was roughly comparable to that in the F-117, the F-16, and Compass Cope.\(^11\) Global Hawk’s time to first flight (prototype) was somewhat longer than that for the F-16, F-117, and Compass Cope. DarkStar’s timing is more comparable.

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\(^8\)The length of time from EMD initiation to first production aircraft delivery is estimated in all but two cases.

\(^9\)Note that the Medium-Altitude Equivalent UAV Predator ACTD did not build what we consider to be prototype aircraft. The Gnat-750—from which Predator was derived—acted in that capacity.

\(^10\)We use our “equivalent EMD” analytical approach here. The initiation of Phase IIB with the building of the third and subsequent aircraft in each HAE UAV ACTD program signifies EMD initiation.

\(^11\)Compass Cope was a competitive dem/val program of the early 1970s that produced two flying examples of two different HAE UAV air vehicles. The aircraft did not fly autonomously, and the program included no sensor suite or ground station development efforts.
Hawk’s time to first EMD flight is similar to that of the other three programs (this date is estimated in the Compass Cope program).

The most striking difference in the Global Hawk program is the short time span between the first flight of the first prototype aircraft and that of air vehicle 3, which is considered the first EMD-equivalent aircraft. This resulted directly from the ACTD acquisition strategy and allowed what was learned in the building of the first two aircraft to be fully leveraged in the manufacture of the third and subsequent aircraft. Similar production continuity is expected between the building of the final EMD aircraft, air vehicle 7, and the first production aircraft, air vehicle 8.

The F-22 schedule as shown in Figure 3.3 is extremely long compared to any of the other programs shown. The schedule is shown as a reference for just how long the development cycle can be when a tradi-
tional development approach is used for the most sophisticated of weapon system programs.

We conclude that the ACTD acquisition strategy in the HAE UAV ACTD program did not result in an accelerated first flight for either the prototype or the EMD aircraft. However, the core of an ACTD flight test program is its emphasis on quickly demonstrating military utility. Global Hawk did so very early in its flight test program. By the end of the Phase III D&E, Global Hawk had demonstrated its capability for long-distance deployment. Except for the Predator UAV, which was also initially developed under the ACTD acquisition strategy and similarly benefited from OTA designation, no other aircraft demonstrated both utility and deployment capability so early in its test program. By these measures, which are at the core of the ACTD concept, the Global Hawk program was successful.