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THE DEVELOPMENT OF A HANDS-ON UNMANNED AERIAL VEHICLE/REMOTELY PILOTED VEHICLE FLIGHT TEST AND EVAUATION

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14. ABSTRACT
The United States Air Force (USAF) Test Pilot School, the Engineering Directorate, and the 452nd Flight Test Squadron all within the 412th Test Wing of the Air Force Flight Test Center, Edwards Air Force Base, have teamed together to develop an Unmanned Aerial Vehicle (UAV) flight test training course. This paper briefly describes the development of the course and presents the major elements of the course.

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The Development of a Hands-on Unmanned Aerial Vehicle/Remotely Piloted Vehicle Flight Test & Evaluation Training Course

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The United States Air Force (USAF) Test Pilot School, the Engineering Directorate, and the 452nd Flight Test Squadron all within the 412th Test Wing of the Air Force Flight Test Center, Edwards Air Force Base, have teamed together to develop an Unmanned Aerial Vehicle (UAV) flight test training course. This paper briefly describes the development of the course and presents the major elements of the course.

I. Introduction

THE outstanding performance of U.S. UAVs in recent campaigns has been front line news all over the world. Because of UAV successes, Pentagon officials expect to triple spending on unmanned aircraft over the next 7 years, using them to perform what it calls "dangerous, dirty and just plain dull missions." Those tasks include attacking enemy radar and missile sites, as well as conducting surveillance missions that last for many hours—missions that human crews would find tedious. A Defense Department report released recently said the Pentagon plans to invest $10 billion by the end of the decade in unmanned aircraft capable of a variety of combat missions, increasing the total number of UAVs, under development and in operational use, significantly.[1] All of these new UAVs will require flight test and evaluation to determine their mission readiness before being fielded to the warfighter.

The Air Force Flight Test Center, while best known for its testing of manned aircraft such as the F-16 *Falcon*, the F/A-22 *Raptor*, and the X-35 *Joint Strike Fighter*, also has a rich history and extensive experience testing remotely piloted drones, cruise missiles, and UAVs. The test and evaluation of UAVs poses some unique technical and safety challenges for fight testers. Over the years, AFFTC testers working on programs such as the Medium Range UAV, the Darkstar, the Predator, the Global Hawk, and the X-45 have gained valuable UAV flight test experience and have overcome many obstacles along the way. Now, that wealth of valuable experience will be shared with others in a formal UAV flight test and evaluation training course. The 412th Test Wing's Engineering Directorate, the USAF Test Pilot School, and the 452nd Flight Test Squadron are jointly developing a UAV flight test course to meet the needs of testers who will be evaluating the performance of these new weapons systems. While there are numerous other courses out there that teach the history of UAVs and the academics of UAV technology, this course will be different by focusing on the flight testing aspects. In addition to offering academics covering all aspects of UAV specifics and UAV-payload technology, students in this course will get hands-on exposure via labs and simulators and will be required to conduct an actual flight test exercise using a mini-UAV hosting a sensor payload and real-time data links. The exercise will touch on all aspects of flight testing and test management to include test planning, safety, resources, data collection, data reduction, data analysis, and test reporting.

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Figure 1. UAVs employed in Operation Iraqi Freedom.[1]

As noted, the past few years have seen a significant increase in the use of UAVs in various military operations. Most recently the military branches widely used UAVs in support of Operation Iraqi Freedom (Figure 1). The military successes with UAVs in the Afghanistan and the Iraq campaigns have led to an explosion in UAV development. As seen in Figure 2, the U.S. DoD funding profile reflects these successes. As you can see in fiscal year 05, the DoD has programmed $2 billion toward UAV development.[1] Other recent contract awards by Defense Advanced Research Projects Agency (DARPA) indicate a commitment to increased UAV development,[2] and UAVs worldwide face a dynamic and growing market.[3]

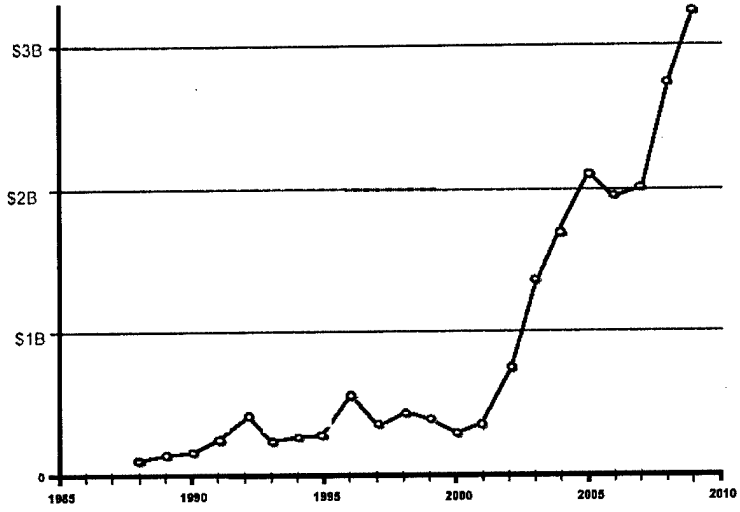

Figure 2. DoD UAV spending profile based on FY04 program baseline.[1]

Although exciting and invigorating to the UAV community, this wide-spread support and development of UAVs brings with it many challenges. On the government side, these challenges include a need to develop a disciplined approach on how we acquire UAVs to meet the mission need statements of the combat and intelligence forces. If you look at how government acquisition

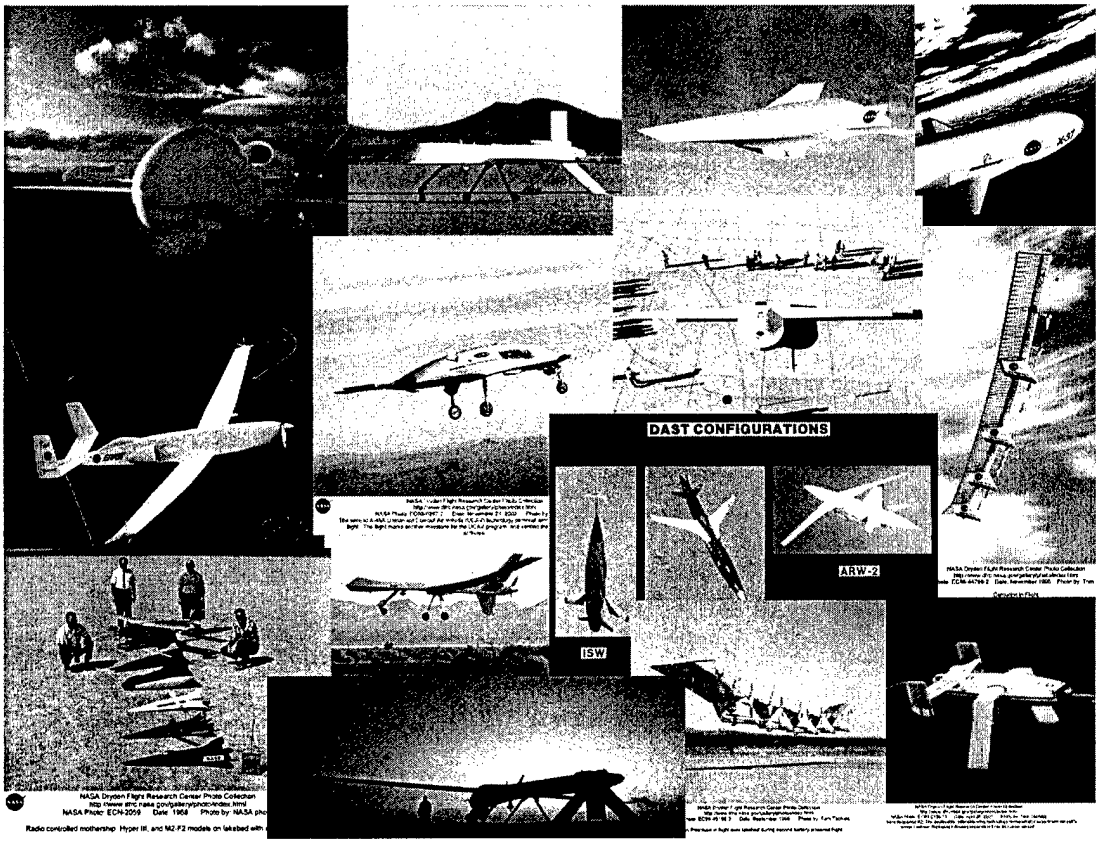

Figure 3. UAVs tested on the Edwards complex or in the near vicinity.

programs are structured, test and evaluation plays a significant and very important role in the development process. The main goal of the test and evaluation community is to provide proven warfighting capabilities on time and on cost to the users.

This paper discusses the development of a UAV flight test course at the Air Force Flight Test Center. This course will be built upon the rich heritage of UAV flight testing at Edwards (Figure 3).

II. Course Description

A. Course Mission and Objectives

The first task of the course development team was to define the course mission statement for the UAV flight test course. The course mission statement for the UAV flight test course is:

To educate and train personnel on the various aspects of flight testing Unmanned Aerial Vehicles (UAV), Unmanned Combat Aerial Vehicles (UCAV), and Remotely Piloted Vehicles (RPV).

The development team then defined course objectives to guide the development of the course curriculum. The overarching objectives, again focusing on the flight test aspect of UAVs, are:

- Understand the *test management* of UAV testing
- Demonstrate proper *test discipline* in the test of RPVs/UAVs
- Understand and demonstrate the *test control* of UAV testing
- Comprehend the *missions* and *systems* architecture of UAVs
- Comprehend the integration of UAVs with the *intelligence* community and the *combat* forces
- Understand the test unique aspects for the *systems* associated with UAVs
- Understand the testing used to determine the *performance* and *flying qualities* of UAVs

Edwards Air Force Base community is the right place for hosting a UAV flight test course. Not only does Edwards offer a rich heritage of flight testing, but it also provides a rich heritage of UAV test and evaluation as well as UAV research and development (see Figure 3).

B. Plan of Instruction

An initial cadre of people representing the Air Force Flight Test Center set off on developing a course designed to meet the test and evaluation training needs of engineers, managers, and developers of UAVs. The organizations represented from the center included the USAF Test Pilot School, the Engineering Directorate of the 412th Test Wing, and the 452 Flight Test Squadron. A list of course modules was developed, guided by the course mission statement and the course objectives listed above. The team developed a list of academic subjects, labs, sims, and a flight test project to provide the students with a hands-on, interactive learning experience. The hands-on applications will be used throughout the course to continually reinforce the academic subjects. These experiences will allow students to practice and gain field experience with the various UAV subject areas.

C. Academics

A list of subject areas is given in the course syllabus (see Table 1). The main focus for the academics is centered on the UAV systems and how they function together to accomplish the various UAV and UCAV missions. The development team placed heavy emphasis on the sensors used aboard UAVs. Another area of emphasis is given to the integration and interoperability of the systems working together as a single unit, and how these systems and system-of-systems operate in the larger force structures.[4, 5]

A block of flight mechanics is also presented as these vehicles must take-off, fly, and land (or hit a target if the vehicle is a stand-alone killer type UAV) for success against their assigned tasks. Other academic modules will address subjects on: range testing issues, the safety planning process as applied to UAVs, airspace issues and coordination with the civilian National Airspace System, UAV logistics, ground systems testing, navigation and avionics systems, data links, and other various applicable modules (see Table 1).

D. Labs

As a reinforcement to the academic modules, the students will participate in various labs for hands-on training. The labs are listed in the course syllabus (see Table 1) and include a lab on electro-optic and infrared sensors, Synthetic Aperture Radars (SAR), mission planning, and frequency management. In addition, students will participate in a Global Hawk simulation flight test exercise on the Global Hawk simulators. In this exercise, the students will participate in a replication of real test points for the program and provide a debrief to course instructors and to members of the Global Hawk test team.

E. Flight Test Project

To further reinforce the academics, students will conduct a flight test project on a mini-UAV (see Figures 4 through 6 and Table 2). This project will give students the chance to apply the academics they have learned in the classroom to an actual system in the field. All of the major components of the system including the flight vehicle, ground station, launch and recovery system, sensor suite, navigation system, etc. will be evaluated by the students.[6] Students will develop limited test cards to meet certain instructor provided test objectives of the project as described by a set of instructor developed program documents to include: the test plan, test and evaluation master plan, operational requirements document, concept of operations, and mission need statement. The students will be able to show traceability from their test points back the applicable acquisition documents after the completion of their flight test project.

Furthermore, future training is envisioned to include training exercises and advanced UAV flight test technique development on the mini-UAV to include flight testing to determine aerodynamic parameter identification,[7] expanded data link training exercises and research,[8, 9, 10] and advanced training on the flight testing of UAV sensor systems.

Table 1. UAV flight test course syllabus.

Week 1

Day	Time		Event	Hours
Mon	0800	1	Welcome Comments	1.0
Day 1	0900	2	Keynote speaker	1.0
	1000	3	History of UAVs	2.0
	1200		Lunch	
	1300	4	Current UAVs and capabilities	1.0
	1400	5	Course overview	2.0
	1600		Dismiss	
				7.0
Tues	0800	6	UAV missions	2.0
Day 2	1000	7	EO/IR academics	2.0
			Lunch	
	1300	7	EO/IR academics	2.0
	1500	8	EO/IR FTT	2.0
	1700		Dismiss	
				8.0
Wed	0800	9	SAR academics	4.0
Day 3	1200		Lunch	
	1300	10	SAR FTT	2.0
	1500	11	X-45 system brief	2.0
	1700		Dismiss	
				8.0
Thur	0800	12	Link 16 Data link & C2	4.0
Day 4	1200		Lunch	
	1300	13/14	EO/IR - SAR sim lab	2.0
	1500	14/13	SAR sim lab - EO/IR lab	2.0
	1700		Dismiss	
				8.0
Fri	0800	15	Wideband Data link (sensor up/dn links)	4.0
Day 5	1200		Lunch	
	1300	16	Global Hawk brief and tour	4.0
	1700		Dismiss	
				8.0

Week 2

Day	Time		Event	Hours
Mon	0800	17	RF Principles for EW	2.0
Day 6	1000	18	Directed energy	2.0
	1200		Lunch	
	1300	19	EW tow decoy/self protection	2.0
	1500	20	UAV weapon systems	2.0
	1700		Dismiss	
				8.0
Tues	0800	21	Navigation systems	4.0
Day 7	1200		Lunch	
	1300	21	Navigation systems	2.0
	1500	22	GATM/TCAS	2.0
	1700		Dismiss	
				8.0
Wed	0800	23	Mission planning	2.0
Day 8	1000	24	Airspace/NAS/FAA	2.0
	1200		Lunch	
	1300	25	Range safety & test safety	2.0
	1500	26	X-45 tour	2.0
	1700		Dismiss	
				8.0
Thur	0800	27	Aero Mechanics	1.5
Day 9	0930	28	Propulsion systems	1.5
	1100	29	Launch and recovery	2.0
	1300		Lunch	
	1400	30	Logistics	1.0
	1500	31	UAV ground systems testing	2.0
	1700		Dismiss	
				8.0
Fri	0800	32	Global Hawk Sim pre-flight brief	1.5
Day 10	0930	32	Global Hawk Sim / Shelter tour	3.0
	1230		Lunch	
	1330	32	Global Hawk Sim de-brief	2.0
	1530	33	Global Hawk lessons learned	1.5
	1700		Dismiss	
				8.0

Week 3

Day	Time		Event	Hours
Mon	0800	34	Human factors/Computer interface	2.0
Day 11	1000	35	Frequency management	2.0
	1200		Lunch	
	1300	36	UAV Flight test prep	2.0
	1500	37	Frequency management lab	2.0
	1800		Dismiss	
				8.0
Tues	0600	38	Pre-flight brief	2.0
Day 12	0800	38	Test flight	4.0
	1200		Lunch	
	1300	38	Test flight de-brief	2.0
	1500	38	Data download	2.0
	1700		Dismiss	
				10.0
Wed	0800	39	Data analysis	4.0
Day 13	1200		Lunch	
	1300	40	AFSOC brief	1.0
	1400	41	UAV OT&E issues	1.0
	1500	39	Data analysis	2.0
	1700		Dismiss	
				8.0
Thur	0700		Travel to El Mirage	1.0
Day 14	0800	42	Predator brief and tour	4.0
	1200		Lunch	
	1300		Travel to Edwards	1.0
	1400	39	Student project time	2.0
	1700		Dismiss	
				8.0
Fri	0800	39	Student project time	2.0
Day 15	1000	43	Project graduation presentations	2.0
	1200		Graduation lunch & Course Debrief	
	1400		Dismiss	
				4.0

III. Conclusion

The Air Force Flight Test Center is developing a UAV flight test course. The recent successful employment of UAVs by the U.S. military forces has led to an explosion in recent UAV development. As the U.S. government moves forward and procures more UAVs to satisfy the "dull, dirty, and dangerous" missions, a structured methodology needs to be applied in the test and evaluation portion of the acquisition cycle to ensure proven warfighting capabilities are delivered on time and on cost to the combat users. To meet this demand, a UAV flight test course is being developed to address the unique flight test aspects of UAVs and UCAVs.

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Figure 4. UAV course flight test asset.

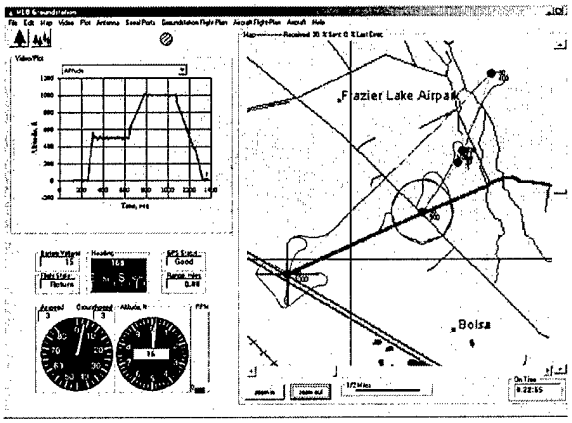

Figure 5. Ground station computer control interface.

Table 2. UAV course flight test asset specifications.

Uses	Short range surveillance and aerial mapping
Powerplant	1.2 cubic inch (23cc) 2-stroke engine
Fuel	Gasoline & oil mixture
Wingspan	72 inches
Gross weight	15.0 lbs (maximum)
Payload	4.0 lbs
Speed	25 to 50 mph
Duration	2.5 hours (nominal); 6 hours (maximum)
Altitude (maximum operating)	9000 feet
Range	7.0 mile radius (telemetry limited); 180 mile fuel range
Sensors	Color CCD video camera with 45 deg FOV. Three-axis stabilized gimbal mount with 17 deg and 45 deg FOV color cameras. IR video and still cameras available.
Data Link	72 Mhz uplink, 2.4 GHz downlink for video and 1200 baud flight data, 800 mw video transmit power.
Launch	Autonomous launch using bungee-powered catapult
Recovery	Automatic return-to-base with autonomous GPS landing on wheels
Guidance	GPS waypoint navigation using MLB flight controller with IMU. Aircraft operates autonomously from launch through landing. Waypoint changes can be made when aircraft is in telemetry range.
Ground Station	Video receiving and recording station for color camera. PC laptop with moving-map and flight data displays is used to monitor the flight and store data.
Uplink	Radio control 8 channel PCM uplink on 72 MHZ for in-flight commands. when under manual control.
Support equipment	Engine starter, power supplies, antennas, shipping cases all included in standard system.
Training and Support	MLB offers support (flight operations, flight training, and repair) at additional cost. Travel expenses and parts are charged additionally.
Warranty	Warranty against manufacturer defects for 30 days after delivery.
Price	Standard Bat system with one vehicle, ground station, catapult, and basic training starts at $42,000 for US customers. Delivery date specified on receipt of order

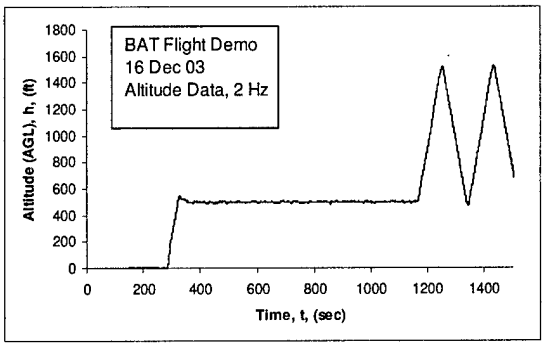

Figure 6. AGL altitude data.