Design and Development of the RF-5E Aircraft

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An objective was established within the Northrop Corporation to determine the best method for providing upgraded tactical reconnaissance capability for the many air forces throughout the world using the F-5 aircraft. The completion of these studies resulted in an aircraft configuration that consisted of a single cockpit F-5E modified with a new forward nose, which included a sensor pallet concept and "Vee" panoramic windows. Since the quantities of this new RF-5E aircraft required by any potential user would not be sufficient to justify the development costs, the decision was made to develop the aircraft with company funds and amortize the costs over production deliveries. A prototype demonstration vehicle was designed and built to permit potential users to evaluate flyable hardware as opposed to a paper concept. The conclusion reached from those efforts is that this is a viable concept which was accepted by the evaluators and resulted in the sale of the aircraft.

Introduction

IN the mid-1970s, the requirements for tactical reconnaissance became more important to air forces throughout the world as the need for more accurate and timely intelligence data was recognized as essential during times of tension or conflict. It was accepted that the primary and most cost-effective method of obtaining this intelligence data was through the adaptation of a tactical fighter as a highly maneuverable vehicle to be utilized as a platform on which to mount the necessary sensors to be used to collect these data. In response to requests from existing F-5 users and potential customers, Northrop initiated a series of studies to evaluate tactical reconnaissance (TR) requirements and how these requirements could be met with an F-5E- or F-5F-type aircraft.

As a result of these studies, some significant requirements and concepts surfaced which were major factors in the final design of a TR aircraft proposed by Northrop. These factors are listed below:

1) The primary TR requirement for each country is basically the same, and that is to collect intelligence data. However, the detail sensors to be used, operational conditions, and specific information required will vary considerably. Hence the need for a multimission reconnaissance capability.

2) The reconnaissance data requirements favored using internal aircraft installation as opposed to pod installation for the sensors. A pod concept has severe limitations in performance and its lower cost is misleading.

3) The force structure mix in a typical air force is such that a single country would not require many reconnaissance aircraft and could not afford to absorb the development costs for a unique reconnaissance reconfiguration. The requirements of many countries would have to be combined and the aircraft designed to meet all of these multioperational needs without an overall cost/performance penalty.

4) If a reconnaissance aircraft could be developed within the F-5 family, it became apparent that Northrop would have to meet as many individual requirements as feasible, and coordinate the design and development to meet these requirements. There would be advantages to accepting an RF-5E for a basic F-5E air force, but Northrop would have to fund the RF-5E development like a commercial program with the intent of recovering this investment upon later sales of the aircraft and through an amortization procedure.

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During the tradeoff studies conducted by Northrop, the RF-4 continually appeared as the standard for comparison, since it was the primary tactical reconnaissance aircraft in the U.S. inventory, and utilized a variety of state-of-the-art sensors. However, it became very apparent that this aircraft was designed for the U.S. requirements, which in some ways differ greatly from other air forces. These differences are listed below.

1) The air force of a typical country is operating from a defensive posture as compared to the USAF requirement to deploy anywhere in the world in an offensive posture.

2) The typical air force is operating over friendly, familiar territory vs new unknown areas with USAF.

3) Tactical and strategic reconnaissance requirements are combined in many countries.

4) Only one type of reconnaissance aircraft is available in some countries for intelligence data collection vs USAF collection capability of aircraft and satellite data.

5) Armament capability, including two missiles and one gun, is retained owing to multimission requirements of various countries' air force structure.

6) Peacetime usage is important in monitoring borders and adjacent water passages.

7) Photographic film-type sensors are very efficient and cost/performance-effective data collection systems are compatible with the using air force resource capabilities.

Development Decisions

Following completion of these studies, Northrop's Tactical Reconnaissance Aircraft Design was finalized and was based on the single-place F-5E modified to utilize a pallet design concept to provide a variety of reconnaissance mission capabilities. This proposed aircraft was designated the RF-5E. In presenting this concept to the various countries, it became apparent that 1) Northrop would definitely have to fund the production development program to get it started; 2) Northrop would have to build a demonstration aircraft to prove the platform and sensor capability in order to eliminate the paper airplane concern; and 3) Northrop would have to provide an opportunity for a prospective customer to evaluate this aircraft on a "fly before buy" policy to verify the capability to meet that individual customer requirements. Development of the RF-5E began in the mid-1970s with the preliminary design completed in 1976. Northrop Corporation initiated a company-funded program in April 1978 to modify a basic F-5E test aircraft into an RF-5E demonstration aircraft. Design, fabrication, and installation were completed within 10 months to permit the first flight in January 1979. Since then, over 168 evaluation flights have been completed, with a total of 18 different countries' air force pilots having flown the RF-5E and evaluated its reconnaissance capability.

Changes have been introduced into the production configuration based on these pilots' recommendations and on their countries' evaluation.

This paper deals with the basic production design and the tradeoffs incorporated in the demonstration RF-5E design in order to provide a viable cost-effective vehicle within the short time span of 10 months. Design emphasis was placed on meeting these primary objectives: 1) to complete the design and fabrication within the 10 months planned and promised, 2) to verify that the reconnaissance-nose structure did not degrade the basic handling and flying qualities of the F-5E, 3) to prove that the RF-5E is a good sensor platform and can meet the data acquisition requirements in the corners of the operational flight envelope, and 4) to verify the validity of the maintainability concepts in which considerable design effort had been expended. In addition to these primary objectives, other considerations were given to detail designs and their overall impact on the program.

Reconnaissance Aircraft Mission Flexibility

Rapidly changing scenarios and potential new hardware development make it mandatory that tactical reconnaissance systems provide full-flight envelope data acquisition capability and growth to new sensors, including photographic or electro-optical. These sensors may be vertical or oblique looking, but the trend appears to be shifting more toward the standoff oblique. The pallet concept in the RF-5E was adapted as the key to mission flexibility and aircraft convertibility, as well as providing future sensor growth capability.

During peacetime, but in periods of tension, border surveillance is recognized as a primary application of high-altitude, long focal length standoff oblique reconnaissance.

This intelligence gathering capability is a "must" requirement for many countries, with the trend pointing toward longer and longer focal lengths. This long-range oblique photography (LOROP) or standoff oblique photography requirement is also important in the tactical reconnaissance usage during conflict.

Owing to the increasing possibility in any future conflict of very strongly defended target areas, combined with a limited number of aircraft resources and trained personnel available to many air forces' commands, overflights of these targets may not be worth the risk. This results in an operational preference that data be obtained from standoff sensor imagery; however, the capability must be maintained within the aircraft system to permit the mission flexibility of overflight or standoff imagery collection.

RF-5E Design

The production design of the RF-5E is described in this section in order to establish the basic configuration of the RF-5E. Some of its capabilities were deleted from the demonstration aircraft, since they were not compatible with the cost-schedule effectiveness guidelines for meeting the primary goals of the program to demonstrate platform performance and handling. These will be described in a later paragraph.

The RF-5E is basically the latest version of the single-seat F-5E, with a new forward fuselage nose that is 8 in. longer and provides approximately 26 ft^3 of volume for the sensors. (See Figs. 1 and 2.) The nose section accommodates one forward oblique sensor, aft of which the main reconnaissance bay extends approximately 5 ft, with "Vee" windows and a retracting i.r. linescanner door incorporated into the lower fairings. This bay is large enough to accommodate three reconnaissance sensors in the baseline design. The recon system design features a versatile palletized concept in which the sensors in the main sensor bay are mounted on a common structure (pallet) which is inserted through the bottom opening door and bolted to the air vehicle structure. The Vee windows permit up to 190 deg angular coverage with the basic sensors, and eliminate the need for right and left oblique windows and additional left and right oblique sensors. Figure 3 shows the bottom of the RF-5E with the two Vee windows and an open i.r. linescanner door.

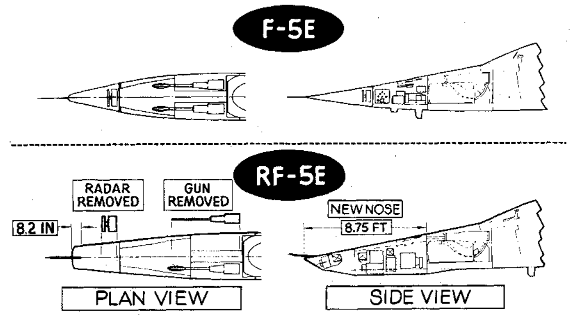

Fig. 1 F-5E/RF-5E configuration comparison.

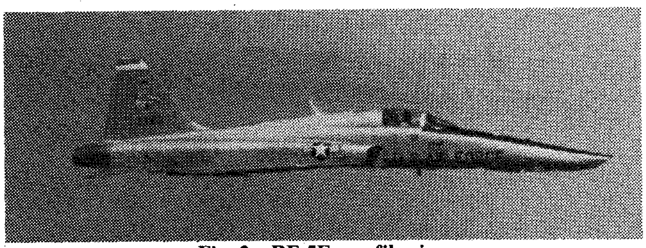
Fig. 2 RF-5E, profile view.

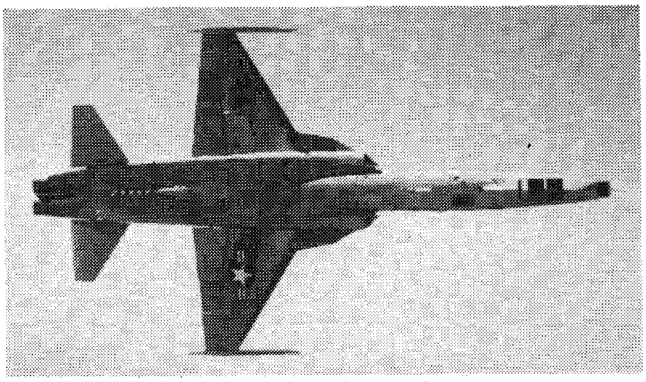
Fig. 3 RF-5E, bottom view.

The RF-5E nose design accommodates the latest high-performance reconnaissance sensor systems with a minimal increase in the air vehicle nose cross-sectional area and no significant decrease in performance or stability. The RF-5E design optimizes air vehicle utilization by providing recon mission flexibility through sensor interchangeability on a mission-to-mission basis, with quick air vehicle turnaround and easy camera servicing. Operationally, a mixture of pallets, each having different sensor configurations among several aircraft, will decrease the need for pallet changes.

The APQ-159 radar system and one M-39 30-mm gun system, located in the right-hand gun bay, are deleted to provide volume for the main reconnaissance sensor bay forward of the gun bays, and for the relocation of avionics and electrical equipment to the converted right-hand gun bay. The left M-39 20-mm gun is retained, which, along with the wing-tip AIM-9 missiles and weapons pylons, provides a self-defense capability. Accessibility to all reconnaissance sensors for optical filter change, electrical hookup and checkout, and film magazine change is provided by the forward nose structure, the five-sided opening film magazine access doors, and the camera linescanner pallet access door. Avionics equipment accessibility is provided by retaining the right-hand gun bay doors. Owing to the small cross-sectional size of the RF-5E and the family of sensors required for best performance, a full complement of RF-4-type sensors cannot be carried at one time. The palletized concept permits mission

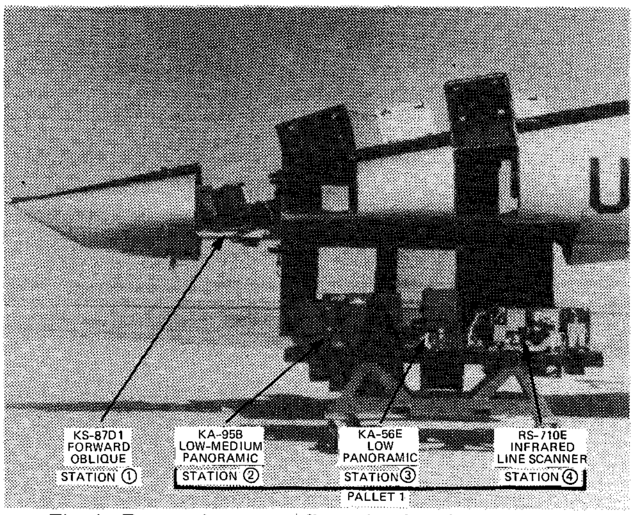

Fig. 4 Reconnaissance configuration 1 equipment station.

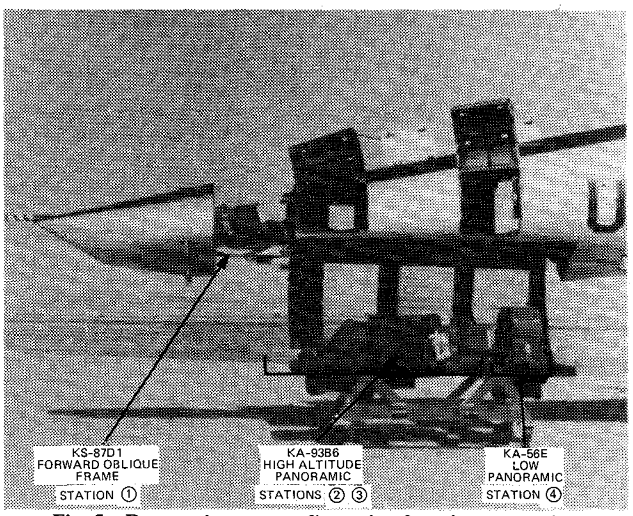

Fig. 5 Reconnaissance configuration 2 equipment station.

specialization using the best sensors available for the mission. A mix of aircraft with different pallets will provide the unit with good flexibility.

In addition, the use of a pallet permits rapid sensor installation and the adaptation to other sensors that might be required by the customer in the future. The RF-5E provides three basic reconnaissance configurations. Reconnaissance configurations 1 and 2 were designed and evaluated on the demonstration aircraft (see Figs. 4 and 5). Reconnaissance configuration 3 will be an option on the production aircraft (see Fig. 6).

Reconnaissance Configuration 1

Forward Nose Compartment

A KS-87D oblique camera is mounted in the nose compartment (sensor station 1) for this pallet configuration. Missions for the KS-87D include forward oblique photography along the line-of-flight at low and medium altitudes. Lenses with Focal lengths of 6 and 12 in. are provided. (See Fig. 4.)

Main Sensor Bay

Pallet 1 has three sensors (stations 2, 3, and 4) optimized for low-to-medium-altitude reconnaissance missions. It contains a KA-95B panoramic camera, a KA-56E panoramic camera, and an RS-710 linescanner. The KA-95B camera manufactured by CAI has a focal length of 12 in. and obtains detailed information from 2,500 to 20,000 ft. The KA-56E manufactured by Fairchild is used for cross-track scanning, low-altitude photography (from 100 to 5000 ft) and has a 3-in. focal length. With capabilities for both day and night missions, the RS-710 provides infrared linescanner imagery and is manufactured by Texas Instruments. It is similar to the VKA-702 unit currently operational in Europe. It obtains good detail in the 200-3000-ft range, and can detect temperature differences of approximately one-fifth degree Celsius in the far IR spectral region. These are shown in Table 1.

Combat mapping or mosaics can be accomplished with pallet 1 by removing the RS-710 infrared linescanner, relocating the KS-87D frame camera from the forward nose compartment to a vertically offset position on the main pallet. The KA-95B or KA-56E would still remain on the pallet with the KS-87D installed in the mapping mode.

Reconnaissance Configuration 2

Forward Nose Compartment

A KS-87D oblique camera is mounted in the forward nose compartment (station 1) for this pallet configuration also. Missions for the KS-87D include forward oblique photography along the line-of-flight at low and medium altitudes. (See Fig. 5.)

Main Sensor Bay

Pallet 2 (stations 2, 3, and 4) is configured for high-altitude panoramic photography using the KA-93B6 camera and low-altitude photography using the KA-56E camera. The KA-93B6 provides detailed panoramic coverage from 10,000 to 50,000 ft and also can be used in a medium-range standoff photo mode for either a left or right oblique photo mission with up to 15-n mi. standoff range for vehicle-size targets. For low-altitude photography from 100 to 5000 ft, the KA-56E provides 180-deg coverage. (See Table 1.)

Reconnaissance Configuration 3

Forward Nose Compartment

The forward nose compartment (station 1) is empty.

Main Sensor Bay

Preliminary design has been conducted so that with additional development a long-range oblique photo camera with a 66-in. focal length f/5.6 lens can be installed on the pallet in the main sensor bay (stations 2, 3, and 4). This pallet configuration is designated pallet 3. A mold line change is required, but it can be installed on the basic RF-5E. This camera is designated KS-147A and is manufactured by CAI, Recon Optical, and is a compact version of the KS-127 developed for the RF-4. It is to be utilized for the high-altitude standoff oblique imagery at distances from 20 to 50 miles, with a 30-n. mi. design point (see Fig. 7).

The KS-147A will provide either left or right oblique imagery through two windows in the main lower access door. This door is different from but interchangeable with the standard Vee door used with the KA-95B and KA-93B cameras. The door for the KS-147A is three-faced with an oblique window on each side. This is shown in Fig. 6. Two-way interchangeability of the doors enhances the mission flexibility inherent in the pallet concept (Fig. 6).

The camera can be operated in either a single frame with 56% overlap or in a multiple three-frame series with side overlap to expand the lateral angular coverage of the KS-147A. The cycle rate will be automatically controlled to provide 56% overlap between each series of three frames. These three photos will provide a total lateral coverage of 11 deg (3.9 deg per frame with appropriate side overlap between the three frames). Cockpit controls will permit the pilot to select single-frame (3.9-deg) coverage or multiple-frame (11-deg) coverage over a depression angle range from 10 to 30 deg below the horizon. An oblique sight will be provided on each side of the cockpit to aid the pilot in acquiring the target area

Table 1 RF-5E reconnaissance configurations

Reconnaissance configuration No.	Nose compartment (forward oblique) Station 1	Main reconnaissance sensor bay (vertical and side oblique) Station 2	Station 3	Station 4		
				Pallet 1		
1 Low medium altitude, day/night	KS-87D1 frame camera; 6-or 12-in. focal length lens (18-deg depression); 5-in. film/1000-ft roll; field-of-view 6-in. lens, 41 deg; 12-in. lens, 21 deg	KA-95B panoramic camera; 12-in. focal length lens; 5-in.-film/1000-ft roll; vertical scan angles 40, 90, 140, 190 deg; oblique 90 deg left, 90 deg right	KA-56E panoramic camera; 3-in. focal length lens; 5-in. film/1000-ft roll; scan angle 180 deg	RS 710E i.r. line-scanner (day/night sensor) V/H range, rad/s	Mode 1 0.2-2.5	Mode 2 2.5-5.0
				Spatial resolution bench, m rad	8-12 = μ region	
				Across track ($\Delta\theta$)	1.0	1.5
				Along track ($\Delta\phi$)	1.0	2.0
				Thermal resolution, °C	0.2	0.2
				Total field-of-view	120	120
				mechanical roll stabilization film (70 mm): 230-ft roll, and 60-mm image width, deg	±10	±10
				Pallet 2		
2 High/low altitude, day		KA-93B6 panoramic camera; 24-in. focal length lens; 5-in. film/1000-ft roll; vertical scan angles 45, 70, 95, 145 deg; oblique mode 45 deg left and 45 deg right at 40 deg depression angle		KA-56E panoramic camera; 3-in. focal length lens; 5-in. film/1000-ft roll; scan angle 180 deg		
				Pallet 3		
3 Lorop growth option	None	KS-147A-frame camera (5-in. film) 66-in. focal length lens; left or right oblique; single frame 3.9-deg lateral coverage, multiple, three frame 11-deg lateral coverage; active stabilization, auto focus for temperature pressure, distance				

in the center of the camera field-of-view. The standoff distance envelope of the KS-147A in the RF-5E is shown in Fig. 7.

Auxiliary Equipment

To support the basic reconnaissance sensors, the RF-5E has auxiliary equipment composed of an integrated sensor control system (ISCS), an inertial navigation system (INS) LN-33, a radar altimeter APN-229, and a video viewfinder and sensor compartment environmental control system (ECS). The ISCS is installed to provide the RF-5E pilot with semiautomatic camera control. The system receives ground speed and height above ground inputs from the INS and radar altimeter to compute the angular velocity (V/H) for the terrain passing below the aircraft. V/H signals and the camera cycle rates are directed to individual cameras with the appropriate scaling factors required for each sensor. After initial setup, all the pilot has to do is turn the cameras on and off at the proper times with a switch on the control stick.

The ISCS features an Alpha Numeric LED auxiliary data annotation system. This system prints latitude, longitude, time of day, radar altimeter, altitude, pitch, true heading, and roll angle on each film frame to assist the interpreter in locating exact geographical coordinates of the photo and in determining scale factors. A video viewfinder with a cathode ray tube (CRT) display at the top of the instrument panel below the gunsight provides the pilot with an improved vertical field-of-view. Displayed information is picked up by a silicon-vidicon television camera located in the bottom of the

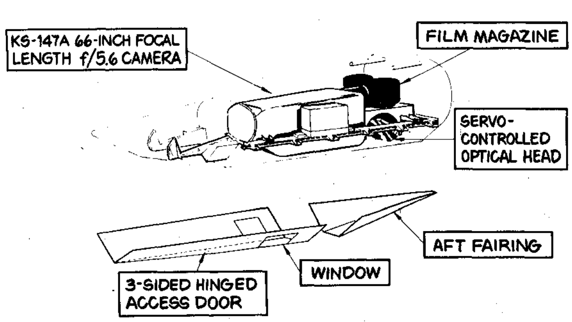

Fig. 6 Reconnaissance configuration 3 LOROP.

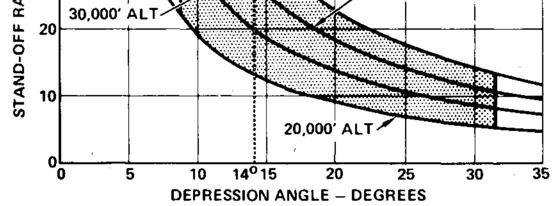

Fig. 7 LOROP camera standoff distances.

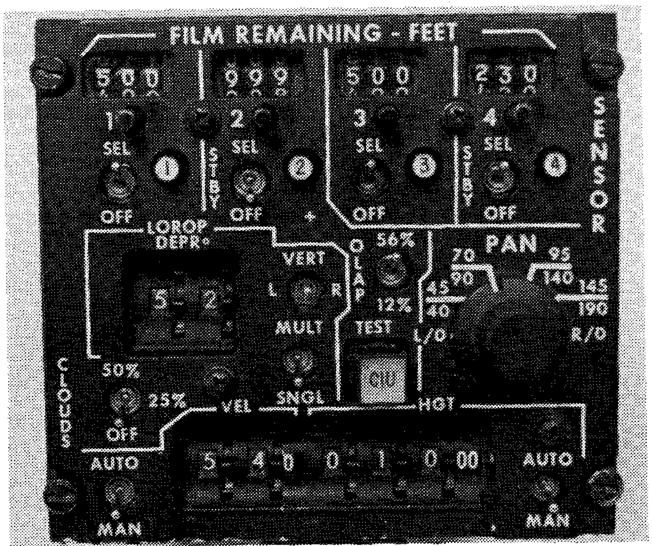

Fig. 8 RF-5E demonstration aircraft reconnaissance control panel.

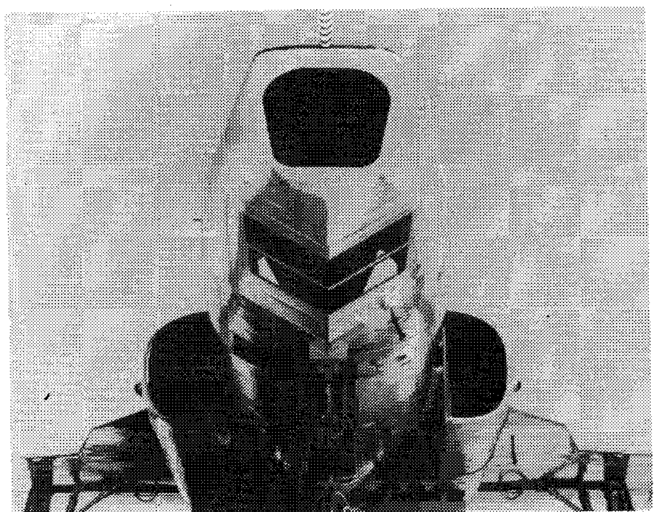
Fig. 9 RF-5E demonstration aircraft reconnaissance sensor windows.

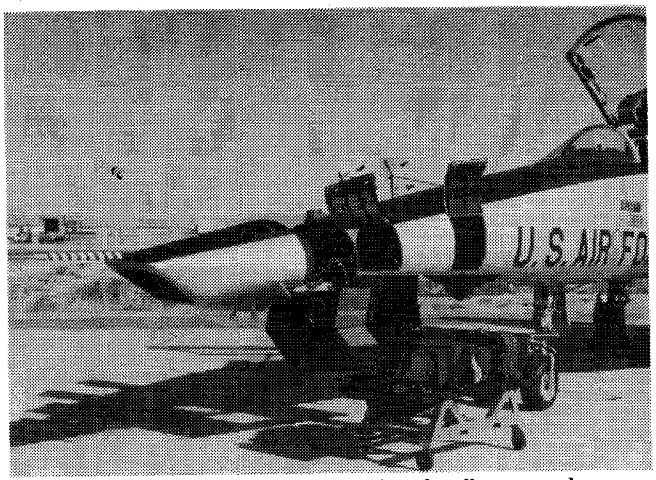
Fig. 10 RF-5E demonstration aircraft pallet removed.

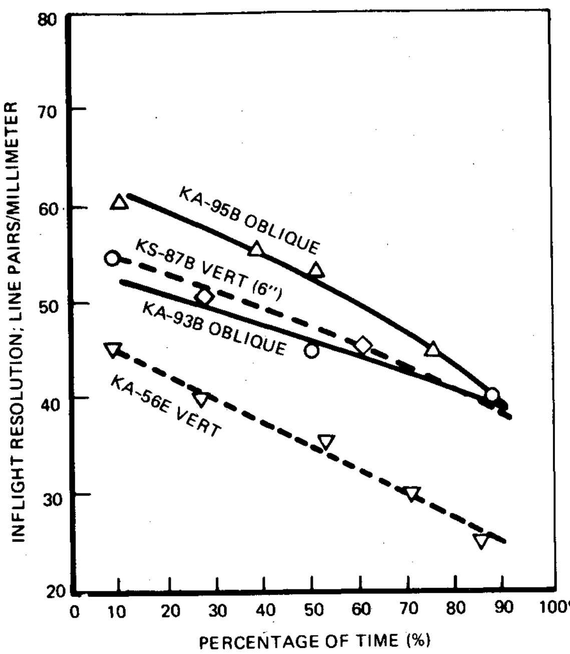

Fig. 11 RF-5E demonstration aircraft reconnaissance sensors resolution flight data.

forward fuselage just ahead of the pilot's feet. The camera is installed pointing down and forward. Its 10:1 zoom lens provides a varying field-of-view. In addition to target location, the pilot can monitor and correct his line-of-flight during combat mapping runs. All the basic aircraft weapon systems capability has been retained in the RF-5E except that one of the two M-39 guns has been eliminated.

RF-5E Demonstration Vehicle Design

In reviewing the primary objectives established for the RF-5E demonstration vehicle, it was determined that certain design activities could be deferred to the production phase. Since the primary test objectives were to verify the basic handling qualities of the aircraft and the sensor platform performance, it was decided that anything not critical in meeting these objectives would be deleted from the demonstration airplane. With all the testing to be accomplished at Edwards AFB, the principal systems thus deferred were the auxiliary equipment and the automatic environmental control system for the sensor and equipment bays. This resulted in an expedited schedule and reduced cost. The auxiliary equipment deleted were the automatic ISCS (a manual system was used and is shown in Fig. 8), the INS inertial navigation system, and the radar altimeter. The reconnaissance configuration 3 sensor (KS-147A) was also deleted from the demonstration program because of its high cost and long development lead time. It was felt that the five sensors utilized in the two basic configurations 1 and 2 would be adequate to establish the RF-5E sensor capability.

An early production F-5E, R1004, which was used as a test vehicle in the early 1970s, was modified by removing the nose forward of the gun bay and installing the new structure for the sensors. The right-hand 20-mm gun was removed and the avionics equipment and T.V. viewfinder camera were installed in this bay. It can be seen that there are no windows on the sides of the aircraft for normal oblique photography. The RF-5E is the first aircraft designed from the start using primary sensors with variable scan panoramic capability in which the scan angle could be either vertical or right or left oblique. The Vee windows utilized for this purpose were made interchangeable with the infrared linescanner door assembly to facilitate this mission flexibility. These windows are shown in Fig. 9. The maintainability aspects of the nose design, including the pallet and access doors, are shown in Fig. 10.

RF-5E Sensor Performance

Performance (Reconnaissance Configurations 1 and 2)

Of prime concern to any operational user of TR systems is how well the camera/aircraft system performs. Resolution targets continue to be the technical communities' acceptable

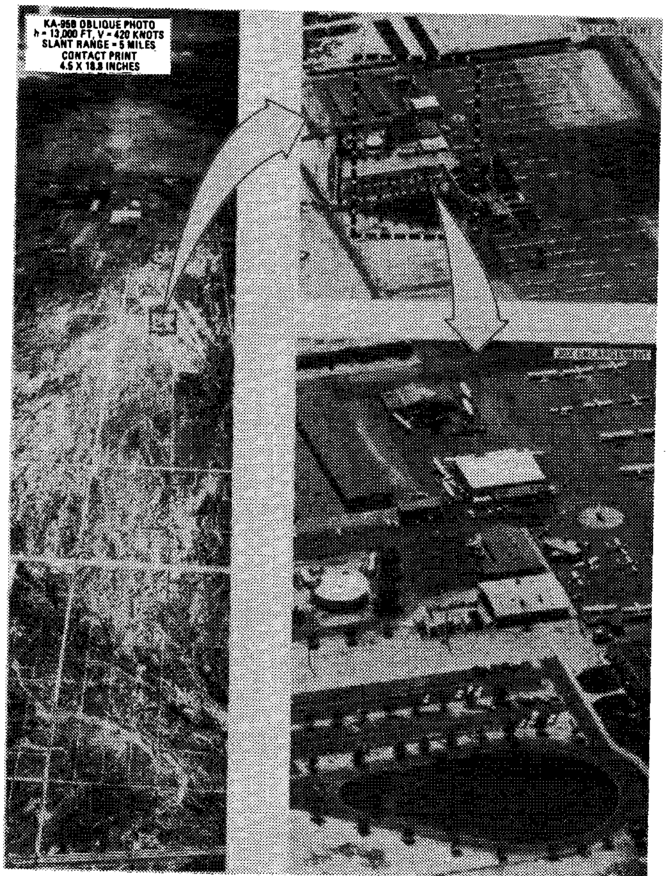

Fig. 12 RF-5E KA-95B photo—Lancaster, California.

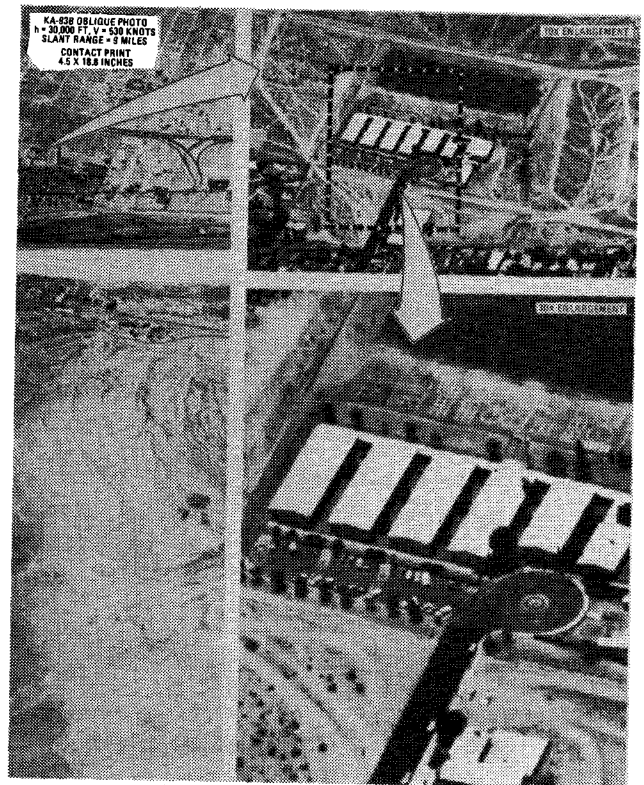

Fig. 13 RF-5E KA-93B6 photo—Barstow, California.

criteria in judging any system, even though there is still no acceptable simple correlation between resolution and tactical imagery performance determination. Testing is done under favorable conditions, i.e., in the Mojave Desert, so that the controllable factors, such as aeroeffects, vibration, temperature, correct *V/H*, etc., can be evaluated and corrected as necessary. The other factors, such as atmospheric haze, shimmer, and low image contrasts, cannot be controlled, but the resulting reduction in resolution is predictable. It is extremely important that the user be made aware of performance under good conditions and that he realize that performance will only be as good and probably less than that when field tested. For these reasons, Northrop has undertaken an RF-5E demonstration program to permit potential users to evaluate in-flight performance.

Pilots from each country who flew the RF-5E were personally aware of the attendant atmospheric conditions. In addition to that, all the film was given to each evaluation team in order to establish consistent performance levels. This consistency factor is very important to the operational user, because it is a value that command can rely on when planning to obtain required information. Performance levels, at least to the 80% level, should be established for consistency. Oblique resolution performance obtained from the standoff sensors (KA-95B and KA-93B6) in the RF-5E demonstration aircraft is plotted vs percentage of time in Fig. 11. For additional information, the KS-87D 6-in. lens and KA-56E vertical imagery is plotted to show the characteristics of the RF-5E platform for both oblique and vertical imagery. The resolution data are plotted from 10 to 90% as a straight-line section and are consistent among the four cameras at approximately the same slope. The data from 0 to 10 and from 90 to 100% are not shown since the tendency is nonlinear. These data are based on approximately 480 resolution target negatives photographed during RF-5E flights over the Edwards AFB Photo Resolution Range.

Standoff Obliques

Medium-Altitude Standoff Photography

The KA-95B was developed for the RF-5E to provide medium-altitude imagery with usable scale for both vertical and standoff targets. Six scan angles were established to provide pilot in-flight options and mission flexibility. These include horizon-to-horizon coverage of 190 deg, vertical scans of 140, 90, and 40 deg. The standoff oblique imagery is acquired with 90-deg oblique scans for both left and right directions covering from 5 deg above the horizon to within 5 deg of vertical. The negative sizes for the vertical scans vary from 4.5×8.4 to 4.5×39.6 in., and the oblique negative size is 4.5×18.8 in. A typical photo representing standoff capability at a medium altitude at 13,000 ft and 420 knots is shown in Fig. 12.

The enlarged area represents a slant range of 5 miles and is an indication of the high resolution of this camera utilizing Kodak 3412 film. As can be seen in the photos shown, the 90-deg oblique scan provides a unique operational capability with low risk of missing the target area.

High-Altitude Standoff Photography

The KA-93B6 is utilized as the basic high-altitude and standoff sensor for the aircraft. This sensor has had operational usage in TR aircraft, and its size, weight, and cost/performance have proven to be optimum for the RF-5E operational requirements. As with the KA-95B, six scan angles were established to provide comparable pilot in-flight options and mission flexibility. The maximum vertical scan angle is 145 deg in addition to the 95-, 70-, and 45-deg scans. The standoff oblique imagery is acquired with 45-deg oblique scans centered at a depression angle of 40 deg below the horizon. The negative sizes for the obliques and vertical scans are the same for the KA-95 with double the scan angle (i.e., KA-95B 90 deg oblique and KA-93B6 45 deg oblique; both have a negative format of 4.5×18.8 in.). The 145-in.-deg scan produces a large 4.5×61-in. negative. The wide-angle coverage of the KA-93B6 oblique standoff (45 deg) eliminates the need for cockpit oblique sights and permits pilot heads-up environment.

A typical photo representing high-altitude standoff capability at 30,000 ft and 530 knots is shown in Fig. 13. The enlarged area represents a slant range of 9 miles and is representative of the camera's high resolution utilizing Kodak 3412 film. The target area of Barstow, California, shown in Fig. 13, was one of the standard standoff targets flown by all evaluating country pilots in the RF-5E demonstration aircraft. A high level of consistency was demonstrated throughout all the flight imagery of this target even though sun, haze, and dust conditions varied considerably during the summer and winter test conditions.

It is intended that this sensor will be the standoff workhorse sensor for the RF-5E, because of its cost/performance tradeoffs, its vertical/oblique operational flexibility, and its effective compromise in focal length vs lateral angular coverage, which are both important in tactical reconnaissance.

Summary

This paper is intended to provide the reader with an insight into the design decisions and tradeoffs that were made in developing the RF-5E aircraft. The principal conclusions resulting from this effort are as follows:

1) Eighteen countries evaluated the system with a resultant high level of consistent resolution performance and many favorable comments. The entire customer evaluation effort was conducted with one set of sensor hardware over a two-year period.

2) The demonstration vehicle concept resulted in the sale of the RF-5E, following a customer flight evaluation and review ("fly before buy") of its tactical reconnaissance capability.

3) The risk of deleting nonessential systems in the demonstration vehicle in order to reduce cost and improve schedule was justified.

4) The design decision to attempt to coordinate and integrate multicountry requirements and to design the basic aircraft accordingly resulted in favorable acceptance by all the evaluating countries.

5) Finally, the demonstration aircraft performance substantiated the initial judgment that the F-5E could be adapted to a good tactical reconnaissance aircraft so that it could logically be introduced into the inventories of those countries currently operating F-5Es. It also verified that the pallet concept could be utilized in multimission operational applications, within the maintainability goals of the F-5E, to meet the reconnaissance requirements of multiple countries in various parts of the world.