FIGHTER COCKPITS OF THE FUTURE

Eugene C. Adam
Staff Director - MDC Senior Fellow, Advanced Crew Systems

McDonnell Aircraft
St. Louis, MO 63166
(314) 234-1060

ABSTRACT

A cockpit revolution is in the making. Many of the much ballyhooed, much promised, but little delivered technologies of the 70's and 80's will finally come of age in the 90's just in time to complement the data explosion coming from sensor and processing advances. Technologies such as helmet systems, large flat panel displays, speech recognition, color graphics, decision aiding and stereopsis, are simultaneously reaching technology maturities that promise big payoffs for the third generation cockpit and beyond.

The first generation cockpit used round dials to help the pilot keep the airplane flying right side up. The second generation cockpits used Multifunction Displays and the HUD to interface the pilot with sensors and weapons. What might the third generation cockpit look like? How might it integrate many of these technologies to simplify the pilots life and most of all: what is the payoff? This paper will examine tactical cockpit problems, the technologies needed to solve them and recommend three generations of solutions.

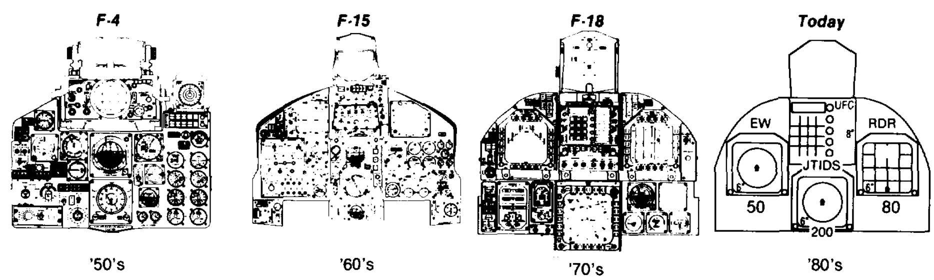
INTRODUCTION

Never has the cockpit designer had such a rich selection of emerging technologies from which to choose. But in these austere times, this treasure trove of technologies is under severe pressure to pay its way in combat kills, safety, or survivability. Therefore, each technology needs to be evaluated on the basis of which problem it solves and the cost effectiveness of the solution.

Before examining these new technologies it might be useful to first examine today's cockpits to see where we stand.

As shown in Figure 1, the analog cockpit of the two-place F-4 Phantom was followed by the HUD/CRT/Analog cockpit of the one-place F-15 Eagle which gave way to the HUD/multifunction display (glass) cockpit of the dual mission, one-place F/A-18 Hornet. Most of the western fighters built since that time use similar cockpit schemes: 1) a Head-Up Display, 2) Some Multi-Function Displays, 3) An Up-Front Control and 4) Hands on Throttle and Stick (HOTAS).

Cockpits have progressed from "steam gauges" to multipurpose displays.



However: The greatest challenge facing today's cockpit designer is to provide the pilot with the necessary Situation Awareness (SA) to be effective in combat. Todays cockpits have difficulty providing that SA because:

- Over 70% of Panel is inflexible
- Only 10 - 20% of Panel provides combat information
- Displays are too small to overlay Radar/NAV/EW/JTIDS on a map
- Display technology is stagnant because of low funding
- Pilot has no Head-Out Information except in the area of the HUD

GP03-0573-2-R

Figure 1. From Round Dials to Multifunction Displays. Where Do We Go From Here?

0-7803-1343-7/93 $3.00 © 1993 IEEE

TWO PROBLEMS

There are two major problems with applying today's cockpit to tomorrow's sensor/mission environment: 1) today's pilot spends more time managing and integrating sensors than executing Tactics and, 2) Useful combat information is available on only 20% - 30% of the instrument panel.

Fiddling and Flying - The first problem requires the pilot to fiddle around with a host of sensors and try to mentally integrate the data from the three primary ones while flying. Radar, EW, and data link are presently displayed on three different displays, on three different range scales with two or three different "ownship" locations. In the past, this has not been an overriding problem because radar search volumes were small and they generally tracked only a few targets, EW systems were inaccurate and full of false alarms and thus largely ignored, and JTIDS/Data Links were aboard very few aircraft. This will however not be the case in the 21st Century. Sensor search volumes will increase at least one order-of-magnitude, EW accuracies will improve and data links will be common. These factors will greatly impact the pilot's ability to remain the "sensor manager/integrator" and have time left over for tactics execution.

Unproductive Space - The second problem, that of inefficient use of the instrument panel space is a straight geometry equation. The average instrument panel is roughly 18" high by 24" wide or about 400 square inches. Using (3) 5" or 6" CRT's yield a total display area of 75 to 108 square inches. Therefore, on average, 70 to 80% of the instrument panel is inflexible, devoid of combat data and unable to contribute to the fight, or bombs on target.

Since hostile contact generally averages only 30 seconds to 2 minutes the pilot has to cope with unfused data on small displays on only a fraction of the instrument panel in a time-critical, high-stress, high-g environment. Not a good formula for making "everybody an Ace".

In combat, the pilot is in the aircraft to make good tactical decisions and execute them. Everything else is secondary. However, the correctness of tactical decision-making is directly proportional to the Situation Awareness (SA) of the pilot.

SITUATION AWARENESS (SA)

So, what is SA, what is it all about? It's simply KNOWING WHAT'S GOING ON SO YOU CAN FIGURE OUT WHAT TO DO! Where are the friendlies, bogies, SAM's and unknowns with respect to my flight? What are their intentions, my intentions and my options? It's obvious that present cockpits, by separating primary sensor data, on different range scales with different "ownship" positions do not give the pilot the SA required to achieve the exchange ratios necessary to win against superior numbers of equivalent quality targets.

The Big Picture - As shown in Figure 2, SA is a two-fold problem: Global and Tactical. Global SA (the Big Picture) generally covers the non-visual spherical world at ranges from 0 to 200 miles. Most often a plan view SA is best, with your ownship position decentered because of higher interest and lethality in the forward hemisphere. However, even in a low-intensity conflict, the 100 mile range display could contain hundreds of graphic elements such as unfriendly surface and airborne threats, friendly surface and airborne elements, unknowns, navigation paths, map and symbolic data. Separate, small displays are no match for this complexity.

The Little Picture - Tactical SA covers close-in visual air-to-air and air-to-surface combat and visual navigation. M on N combat is the arena where man and machine are taxed to their limits. For equivalent machines, the SA acted upon by the eye, brain, hands and feet is the primary determinant of "who shoots" and "who chutes".

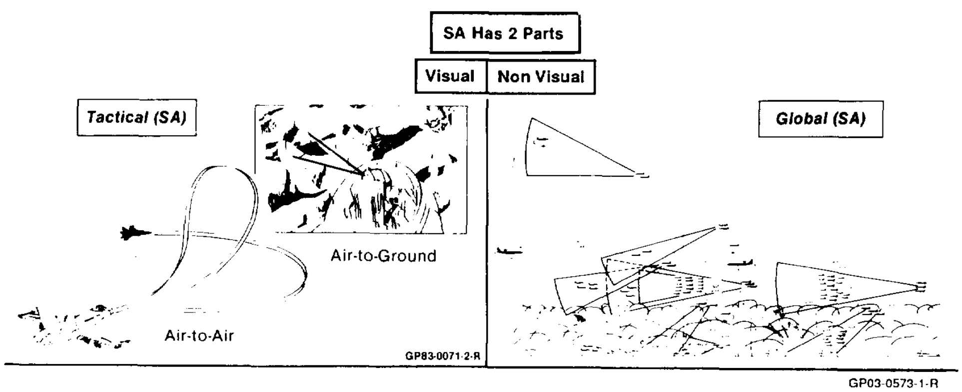


Figure 2. Situational Awareness – "Knowing What's Going on So You Can Figure Out What to Do"

TACTICAL SA SOLUTION

The tactical SA problem is best solved by a helmet system that: 1) TRACKS the pilot's head position and slaves sensors and weapons to the helmet line-of-sight, 2) DISPLAYS combat and flight information on the helmet visor.

Integrated Helmet System - MCAIR and Kaiser Electronics IRADs have designed, built, simulator tested and flown an Integrated Helmet Mounted Display and Sight (HMDS) System called "Agile Eye" (TM) which can increase visual exchange ratios by a factor of 2:1 over a Head-Up Display. The "Agile Eye" is a totally integrated helmet sight and display that has the following features:

a) A HUD type display on the visor,
b) Lighter than present helmets,
c) Improved CG,
d) Improved crash protection,
e) No visual obstructions,
f) Less aero lift during ejection,
g) Improved sound reproduction/ and attenuation.

The "Agile Eye" Helmet uses readily available off-shelf technology cleverly integrated into a pilot centered design that improves every physical and performance characteristic of today's flight helmet. It offers fields-of-view and stroke/raster capabilities that match present day HUD's but with the advantages of off-axis weapon use, three quarters the system cost, two times the reliability and the added safety of attitude and other flight data available at all times, and at all sight angles. All of these features are packaged in a low-bulk, handsome design as pictured in Figure 3.

"Agile Eye" Payoff - In A/A: Faster visual lock-ons, simultaneous AIM-7 and AIM-9 launches, target handoffs to wingman, better attitude awareness at all times. In A/G: off-boresight target designations, offset NAV waypoint updates, target handoffs to wingman. As shown in Figure 4, MCAIR F-15 simulator evaluations using TAC pilots/aggressors/scenarios showed a 2:1 exchange ratio improvement with the "Agile Eye" HMDS over the HUD.

Helmet Systems - The Linchpin - We are convinced that helmet systems are the key to future cockpit improvements; they increase a pilot's performance and free-up panel space.

WHAT IS THE PILOT'S PROBLEM?

1) Next generation sensors, such as RADAR, EW and JTIDS will provide 100's of pieces of information 2) current display technology limits CRT sizes to 5, 6 or 7 inches square, 3) small displays require separation of primary sensors such as RADAR, EW, JTIDS and NAV - leaving the pilot to mentally integrate and fuse this data during the stress of combat.

Picture This! - Three different sensors on three separate displays on three different range scales with "ownship" in three different locations; a formula for confusion. Larger displays solve that problem by fusing all sensor data to a common range scale and coordinate system and overlaying it on a map.

What is the Hardware Problem? - CRT's using a scanning beam naturally grow dimmer as they are made

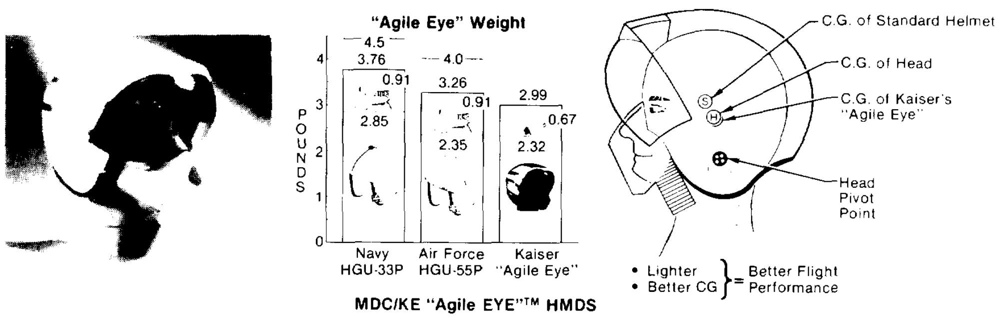


Figure 3. "Agile Eye" a HUD-on-the-Head Without Penalties to the Pilot

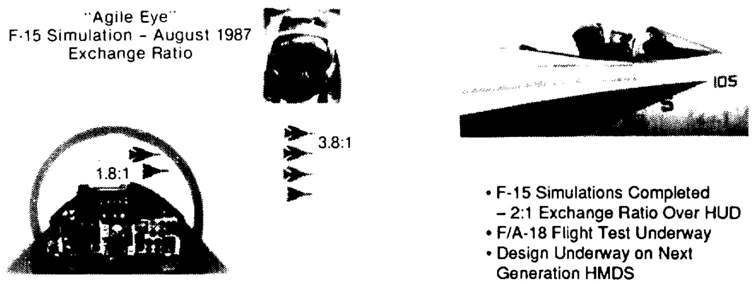


Figure 4. "Agile Eye" Doubles Exchange Ratios

larger which is unacceptable in a high ambient cockpit. Flat panel displays using matrix addressed pixels do not have this problem, but the technology and infrastructure need R&D funds before they can seriously challenge the CRT.

GLOBAL SA SOLUTION

The beyond-visual-range Situational Awareness solution requires the "fusion" of RADAR, EW, JTIDS navigation and map on a large display. This would allow the pilot to look at a single source to "get the Big Picture".

As shown in Figure 5, display size growth has not kept pace with computer and sensor technology because of the lack of serious research and development on CRT alternatives. A two-step solution offers the most cost and schedule effectiveness. In the near term, we must first develop larger, new technology displays on which to display the situation to the pilot. We must then reconfigure the HUD to provide the room to mount this display in the cockpit. In the far term we must develop new, flat-panel matrix technologies that provide display surfaces of 10 to 15 times what is available using today's CRT technology.

COCKPIT 2000: A NEAR TERM SOLUTION

Helmet systems such as "Agile Eye" are essentially a HUD-on-the-head which allows us to reduce the physical size of the aircraft HUD sufficiently to provide room for a 10" x 10" Global Situation Display. This display is a compromise between being large enough to fuse RADAR, EW and JTIDS on a single touch sensitive surface, but yet small enough to leave room for adjacent 5" or 6" auxiliary displays.

As shown in Figure 6, Cockpit 2000 has about 2X the display area of current fighters and differs from today's cockpit in two important aspects: 1) A helmet sight and display provides all normal HUD functions on the helmet visor with the added benefit of off-axis target designation, 2) The 10" x 10" Global Situation Display is larger and more productive than any three, small multifunction displays.

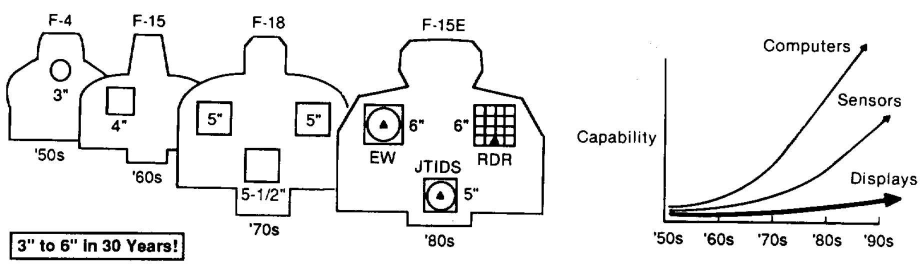


Figure 5. Present Evolution of Displays Not Keeping Up With Computers and Sensors

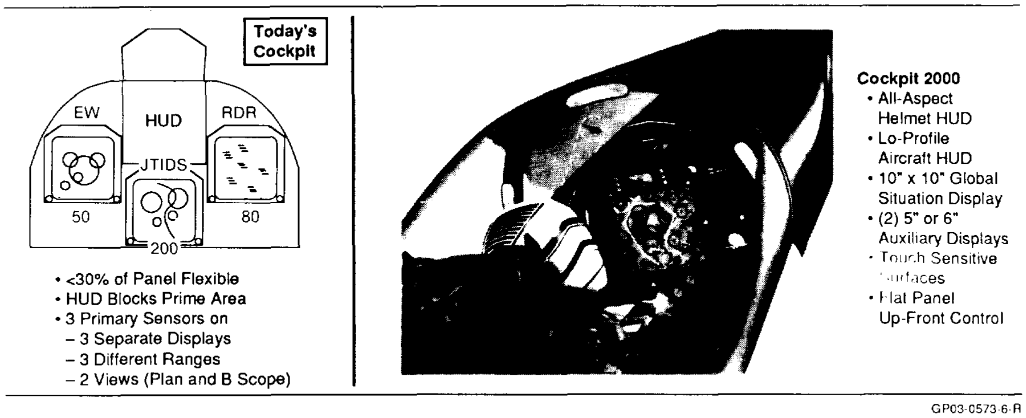


Figure 6. Cockpit 2000 Solves the Two Most Pressing Cockpit Problems, Tactical and Global SA

BIG PICTURE: A LONGER TERM SOLUTION

An increase in display technology R&D will eventually provide flat, matrix display panels with large surface areas, high brightness, high resolution and long life. As depicted in Figure 7, these large displays will provide 10 times the display area of today's CRTs allowing plan and perspective views, split screen, and movable inserts. A Helmet Sight and Display, voice command and touch sensitive surface will provide pilot interface with the weapon system. In short, the Big Picture provides the pilot with full control over the configuration and content of almost 400 square inches of display surface to match the mission-moment-of-interest whether it be air-to-air, air-to-surface, Navigation, TF/TA, or System Status. Manned Simulations have shown a 100% increase in the situational awareness of pilots using the Big Picture over those using a conventional 2 or 3 small MFD (CRT) cockpit.

Display Technology - The CRT has reigned supreme as the display device of choice for almost 100 years, with continuous evolutionary brightness, resolution, reliability and color improvements over that time. In fact, the huge CRT infrastructure and its good performance has stifled any real competitive technology investments until recently.

There are three large markets for a CRT replacement: 1) HDTV promises displays sizes of 2-5 times present CRT devices with the desire to "hang it on the wall" like a picture. 2) Portable PC's up through work stations desire high-resolution, full color, small bulk and for portable applications, low-power consumption. 3) Military and Aerospace all share a similar problem; too much data on too small a CRT surface. Larger displays are required to solve this problem but the bright sunlight conditions in aircraft must also be met which essentially dooms the CRT.

All three of these applications, and their commercial profit potential are giving a massive push to flat panel technologies. The next three years will see a R&D investment in flat panels of at least three times the total CRT alternative investments for the last 30 years. Unfortunately, the U.S. investment is roughly 5% of the worldwide investment, hence our commercial possibilities are few and our defense needs may well be supplied by offshore manufacturing facilities.

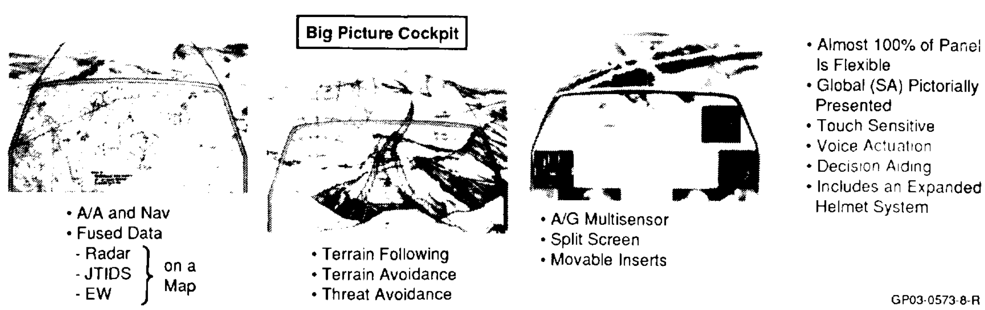


Figure 7. "Big Picture" Provides Total Reconfiguration Flexibility

THE FINAL FRONTIER

The laser, CBR and high energy weapon threat will require radical approaches to protecting the crew and providing sufficient information to fly and fight. There are two broad alternative solutions: 1) Remove the crew from the cockpit and fly and fight using remotely controlled vehicles. 2) Protect the crew within a "windowless cockpit".

Remotely Piloted Vehicles - Two technologies are necessary to provide this capability: 1) Sensors equivalent to the eye/brain are required to capture the visual combat scene real-time. 2) A secure, wide-bandwidth data link is required with near real-time capability to allow a pilot to fly and fight from a remote location.

For convenience, we will not treat this case because, SAM's, cruise missiles and other weapons fill many of these mission functions and the technology and frequency spectrum required for the immense amount of data to be linked between the pilot and vehicle on a real-time non line-of-sight basis make it impractical for any large number of fighters.

Windowless Cockpit - Needless to say, the concept of a sleek fighter without a canopy will cause most pilots to shudder and gag. However, the laser threat is real, they are in the field and 50 mile, zero time-of-flight "dazzles" are on the horizon.

For simplicity let us assume that sensors can provide spherical coverage around the aircraft with visual acuity. With the windowless cockpit concept there are two broad solutions: 1) Retractable protection whereby the pilot flies visual or non-visual depending on the situation and trains both ways. 2) Full time, enclosed cockpits with no outside vision. Both solutions require helmet displays and fixed displays, however, the retractable protection scheme has the disadvantage of having to meet 1000 times the ambient brightness requirement of the fully enclosed alternative.

Helmet vs Cockpit Displays - Without enormous breakthroughs in optics and display devices, the goal of a helmet display that does everything and doesn't require additional head-down displays does not seem practical for the high g environment in the near term. As shown in Figure 8, Cockpit and Helmet Displays are complementary. Both are required and both need extensive R and D to meet the needs of all three generations of cockpits discussed herein.

SUPPORTING TECHNOLOGIES

A number of supporting technologies are needed to gain the full advantages of the three generations of cockpits proposed herein. The real issue, however, is the cost/benefit ratio of individual and combined technologies. These are difficult questions to answer definitively because simulations and tests tend to emphasize environments whereby tested technologies are useful when nobody knows what the eventual distribution of scenarios will actually be. Fortunately, the aerospace industry and D.O.D. have seasoned design teams that are very good at getting the right systems in the final version of new generation aircraft.

Cockpit Displays

- Global Situation
- Plan View
- Beyond Visual Combat

Helmet Display

- Tactical Situation
- Perspective View
- Visual Combat

GP03-0573-7-R

Figure 8. Cockpit and Helmet Displays, They Complement Each Other - Both Are Required for SA