N94-13319

HUMAN FACTOR IMPLICATIONS OF THE EUROCOPTER AS332L-1 SUPER PUMA COCKPIT

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ABSTRACT

The purpose of this paper is to identify and describe some of the human factor problems which can occur in the cockpit of a modern civilian helicopter. After examining specific hardware and software problems in the cockpit design of the Eurocopter (Aerospatiale) AS332L-1 Super Puma, the author proposes several principles that can be used to avoid similar human factors problems in the design of future cockpits. These principles relate to the use and function of warning lights, the design of autopilots in two-pilot aircraft, and the labeling of switches and warning lights, specifically with respect to abbreviations and translations from languages other than English. In the final section of the paper, the author describes current trends in society which he suggests should be taken into consideration when designing future aircraft cockpits.

NOMENCLATURE

ADF	Automatic Direction Finder
ADI	Attitude Deviation Indicator
CDI	Course Direction Indicator
DECCA	Area Navigation System
DME	Distance Measuring Equipment
EFIS	Electronic Flight Info. System
FFCL	Fuel Flow Control Lever
HSI	Heading Situation Indicator
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LORAN	Area Navigation System
MGB	Main Gear Box
NG	Gas Generator Speed
NR	Rotor Speed
T4	Engine Exhaust Gas Temp.
VLF/OMEGA	Area Navigation System
VOR	VHF Omnidirectional Receiver

INTRODUCTION

The Eurocopter (Aerospatiale) AS332L-1 Super Puma is a twin-engine commercial helicopter, primarily designed for passenger transport. It is a derivative of the SA 330 Puma which was developed initially to meet a French Air Force requirement for a medium-sized helicopter able to operate day or night in all weather and in all climates. Although used very little in the United States, the Super Puma is popular in many parts of the world and has been particularly successful in offshore oil market in the North Sea. The AS332L-1 is equipped with Turbomeca Makila 1A1 engines, can carry up to 24 passengers, has a maximum gross weight of 18,960 pounds, and has a maximum cruise speed of 150 knots.

The author flew and instructed in Super Pumas for Helikopter Service A/S of Norway, a North Sea offshore operator, and Trump Air of New Jersey, a FAR Part 135 operator. The information contained in this report comes from over five years and 2000 hours of flying experience in the Super Puma and from over 600 hours of instruction and observation of other experienced professional pilots in a six-axis AS332L-1 Rediffusion simulator owned by Helikopter Service.

It is the author's contention that the optimum cockpit design for any aircraft will not be found by the manufacturer alone. Line pilots and instructors can and should help manufacturers decrease the incidence of human factor errors by providing enlightened feedback about ergonomic problems encountered in the cockpit.

Presented at the Fifteenth European Rotorcraft Forum, Amsterdam, The Netherlands, 1989.

THE SHELL MODEL

The SHELL Model (Fig. 1) is one conceptual model of human factors. In the center of the model, is the human operator, or LIVEWARE. When working with a machine, the operator must contend with SOFTWARE, HARDWARE, the ENVIRONMENT, and other LIVEWARE. A mismatch anywhere in the system causes stress, which decreases efficiency and safety.

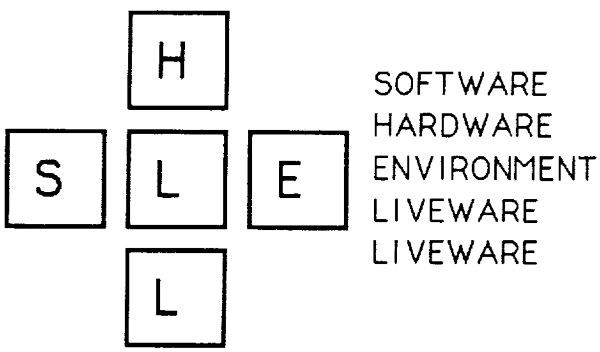

FIGURE 1. The SHELL model of human factors.

HARDWARE relates to the machine itself and, with respect to aircraft, includes such things as controls, displays, warning systems, safety equipment, seat design, and cabin facilities.

SOFTWARE, again in relation to aircraft, includes operating procedures, format of manuals, checklist design, language of information, graphs/tabulation design, and symbology.

ENVIRONMENT includes temperature, noise, vibration, humidity, pressure, light, pollution, and circadian/biorhythmic cycles.

LIVEWARE includes personal relations, crew coordination, discipline, communications, and leadership.[1]

The main concerns of this paper are with the hardware and software portions of the SHELL model. Although there is room for improvement of environmental factors in many aircraft and particularly helicopters, problems with these factors are generally well-known. Liveware factors, i.e. the human-to-human interactions, are usually outside the realm of the designer's influence, although such things as radio and intercom systems, which are also hardware items, have obvious effects on communications. Therefore, both environmental and liveware concerns are outside the scope of this paper.

HARDWARE FACTORS OF THE AS332L-1 COCKPIT

Engine Malfunction Warnings

"OVSPD" warning switch/light. To protect against an engine and rotor overspeed, the fuel control on the Aerospatiale AS332L-1 Super Puma is designed to shut down the engine automatically if the power turbine speed goes too high. Because the main conditions that can cause a power turbine overspeed (high speed shaft or free-wheeling unit failure) happen so quickly, an overspeed warning light (Fig. 2) is provided so that the pilots realize the engine has shut itself down due to an overspeed. This is a good thing to know because one should normally not re-start an engine if this happens.

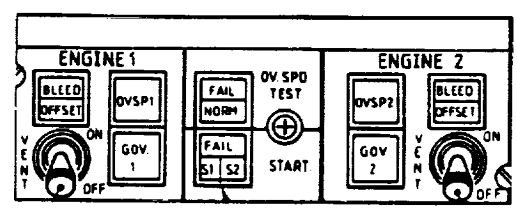

FIGURE 2. "OVSPD" warning switch/light.

A relevant point is that the "OVSPD" light burns steadily when the engine is shut down normally, but the light flashes when the overspeed mechanism shuts the engine down.

This creates a human factors problem. Most pilots have a built-in aversion (although actually it is a conditioned response) to flashing lights in the cockpit. Their immediate gut reaction to a flashing lighted switch is to press the switch to make it stop blinking. A typical example is the master caution light in some aircraft. Another example is the RACAL Avionics RNAV 1 DECCA system which flashes a warning light that must be depressed when there is a problem. There are certainly many other good examples.

How can a flashing light be a problem? Consider the following scenario. First, one engine fails due to an overspeed. The copilot sees the flashing "OVSPD" light, says nothing, and then, unconsciously, presses the light to stop it flashing. Many companies even specify that the first action during any emergency procedure is to extinguish the master warning light.

A few minutes later, the captain, who up to this point has been concentrating on flying the aircraft, considers trying a restart because he didn't see the overspeed warning light flashing and the light is now steady. The copilot, who cancelled the only indication that would tell them they had an engine overspeed, readily agrees to a restart because he cancelled the light without consciously thinking about it. The engine starts normally, because the broken engine-to-MGB shaft has no effect during the starting sequence, but as the pilots increase power, the unburdened power turbine and its broken shaft spin faster and faster until something else breaks. Although this has never happened in flight, there is one instance of a Super Puma engine being re-started by a mechanic on the ground after the engine had shut down due to an overspeed. The aircraft caught fire and was destroyed.[2]

Three lessons can be learned from this example. First, flashing warning lights should only be used for the most serious of malfunctions. Too many flashing lights in a cockpit defeats their purpose, which is to catch the pilots' attention and alert them to a particular problem.

Second, it should only be possible to extinguish a flashing warning light by taking the proper corrective action and removing the hazard. For example, a flashing fire warning light should only go out when the fire itself has been extinguished.

Third, extreme care must be used when designing a switch to function as both a switch and a warning light. If the light in a switch does more than simply indicate whether an item is off or on, the function of the switch must be easily understood at all times and under all conditions. One should not assume that a task people can do under normal conditions will still be error-free when a panic is on.[3]

"POWER" light. Another engine light that causes problems is the "POWER" light. The "POWER" light is under the direction of the power calculation system which is designed to help the pilots determine which engine is malfunctioning under various conditions. Very basically, the power calculation system examines the Ng (gas generator rpm) readings from both engines and the Nr (rotor rpm) to determine which engine has malfunctioned and why; then it illuminates the "POWER 1" or "POWER 2" light as appropriate.

This is particularly good information to provide the pilot when the automatic fuel control of one engine fails and that engine, although still operating, must be controlled manually. Because the other engine automatically varies its power output in order to maintain Nr within limits, it can be difficult to determine which engine is malfunctioning.

The problem with the "POWER" lights is that they don't illuminate until Nr varies approximately 6-7% above or below the usual in-flight setting of 100-101%. Although these Nr values are neither dangerously high nor low, they are well outside the "usual" Nr values.

Notice the use of the word "usual" and not "normal." After one hundred or so hours in any aircraft, most pilots know what the "usual" values are for pressures, temperatures, rpm, etc. As a result, they become suspicious when they see "unusual" values, even if these values are within the specified "normal" limits. When a helicopter pilot observes an "unusually" high or low Nr, his first reaction is to adjust collective pitch to bring the Nr back to its "usual" normal value.

What happens when an automatic fuel control malfunctions and causes the Nr to vary is that the pilot instinctively adjusts the collective pitch to bring the Nr back to where it belongs. This defeats the intention of the power calculator system because it cannot illuminate a "POWER" light unless the Nr is above 107% or below 94%. The pilot is left to figure out which engine is malfunctioning by interpreting the Ng and T4 indications; or he can choose to raise or lower the collective until the Nr changes enough to cause the power calculator to illuminate a "POWER" light, an action which many pilots are reluctant to do.

Autopilot System

General. Any pilot who has ever worked with an advanced autopilot knows that the most frequent mistakes made by pilots, even after they know how the system operates, are:

1) pushing the wrong buttons at the right time,
2) pushing the right buttons at the wrong time,
3) pushing the right buttons in the wrong sequence,
4) thinking that an autopilot function is off when it is on, and
5) thinking that an autopilot function is on when it is off.

A primary cause of these errors is the manner by which the autopilot functions are displayed. Usually, the annunciator lights are shown on one central autopilot panel, which is often on the center cockpit console (easy to reach, but out of sight). Sometimes the annunciators are duplicated elsewhere in the cockpit, on the panels in front of the pilots or even on the flight instruments themselves. For example, airspeed hold may be displayed on the airspeed indicator, altitude hold on the barometric or radar altimeter, localizer and glide slope hold on the HSI (Horizontal Situation Indicator) or artificial horizon (ADI).

Of the three methods, indicating autopilot functions on the flight instruments is the best because this is the method the autopilot annunciators will be seen most often by the pilot. The simple reason is that the flight instruments are an integral part of every experienced pilot's cockpit scan. The autopilot annunciator panel on the center console is not a frequent part of most pilots' instrument cross-check.[4]

AS332L-1 autopilot system. The Helikopter Service AS332L-1 Super Pumas are equipped with SFIM 155 duplex autopilot systems, SFIM CDV 85 four-axis couplers, Collins ADI-77 Attitude Direction Indicators, and Astronautics 133640 Horizontal Situation Indicators.[5]

Mixing boxes from different manufacturers may not always be desirable, but due to economic reasons (mixing may be less expensive), operational considerations (one system may not provide all things to all operators), and marketing aspects (compatibility of systems means greater potential sales), mixing systems is not going to go away. As a consequence, designers of the various components have to pay even more attention to human factor problems and, equally important, there must be someone in the loop who is able to examine the resulting system in its entirety.

With respect to the autopilots in Helikopter Service's Super Pumas, when they work as designed, the autopilots are truly impressive. If there is a malfunction, there are, for the most part, sufficient back-ups and warnings for the pilot. In other words, the autopilot hardware, per se, is generally very good.

However, of all the systems in the Super Puma, it is universally agreed in Helikopter Service that the autopilot is the most difficult for pilots to master. Many of the difficulties with the autopilot stem from human factor problems in the design of the system.

Single- or dual-pilot system? The most basic problem with the system is that it can not be fully operated from the left seat. Certain functions, for example coupled ILS and coupled vertical speed, can only be controlled by the pilot in the right seat. The system favors the captain's side of the cockpit to the detriment of the copilot's side.

The reason was Aerospatiale's original intention to obtain single-pilot IFR certification for the Super Puma. This has not been obtained and may never be, but the result is an autopilot system that makes it difficult or impossible to set up, among other things, a coupled ILS approach from the left seat.

Why is this lack of full dual-pilot capability not good? Consider this scenario: The captain becomes incapacitated, the weather at the airport is at minima, and the copilot is young and inexperienced. He needs all the help he can get, but because he can't reach the necessary switches on the right side of the cockpit, he has to fly the ILS uncoupled.

A good general principle to use when designing autopilot and coupler systems is to make all autopilot functions fully controllable from both seats in the cockpit. There should also be one switch, easily accessible to both pilots, that passes autopilot authority from left to right and back again. And there must be a well-defined annunciator prominently located on the front panel (the best place would be right on the artificial horizon) telling the pilots who has the authority.

With respect to single-pilot IFR, the following policy statement from the International Federation of Air Line Pilot Associations (IFALPA) is appropriate:

> "Although IFALPA recognizes that presently single-pilot commercial operations are in widespread use, this type of operation is not acceptable during international public transport flights, including all off-shore flights, because of the reduced level of safety."

Single-pilot IFR capability is great, but it should be available to both captain and copilot alike.

Heading select switch. The Helikopter Service machines have a switch which is used to transfer autopilot authority between the pilot and copilot, however it only controls the heading select function of the system (Fig. 3). Both pilots have a selected heading index, or heading "bug," on their horizontal situation indicator (HSI) which is used to set a desired heading the autopilot coupler should maintain. The heading select switch tells the autopilot which heading index to follow.

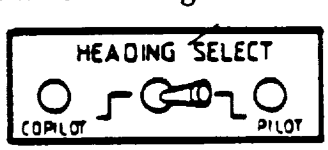

FIGURE 3. Heading select switch.

The idea is simple enough and easy to understand, but the switch and its associated annunciator lights indicating which pilot has heading authority are located on the pedestal console between the pilots, far away from the HSIs and other primary flight instruments. The error, which happens frequently, is that one pilot sets his heading index to the desired heading and, forgetting to check the heading select switch, engages the coupler heading hold. If the switch is still set to the other pilot and his heading index is set at another heading, the autopilot will obviously turn the helicopter to an undesired heading.

This problem could have been avoided by putting the annunciator lights for the heading select switch on the heading indices of the HSIs. When the pilot has heading control, his index is illuminated (or some other way highlighted); when the copilot has heading control, his heading index is highlighted. .

Localizer and glide slope capture modes. The problem with these modes is deceptively small, yet potentially extremely dangerous. The "fix" is probably relatively simple, given the complexities of the rest of the autopilot system.

An Instrument Landing System (ILS) provides precision guidance to a runway while providing very specific obstruction clearances throughout the approach. By regulation and common sense, an aircraft is not allowed to descend on the glide path until it is established on the localizer course.

With the SFIM CDV 85 four-axis coupler, it is possible to arm both the localizer and glide slope modes before being established on either one. This makes sense because the pilots can set up the autopilot before they reach the localizer. What doesn't make sense is that it is possible to capture the glide slope before the localizer is captured, and, in fact, even with the localizer mode un-armed. As a result, the aircraft will descend on the glide slope beam while outside the limits of the localizer, which means that the aircraft could be descending below the minimum altitudes designated for that part of the approach.

Coupler and flight director annunciation. Human factor specialists have often observed that people adapt well to design deficiencies in their working environment. One way Super Puma pilots have adapted to the poor annunciation of the coupler functions is to use the flight director command bars (Fig. 4, #2 & 6) on the ADI as an indication to them that the coupler is on. With the command bars right on the instrument they look at most often, the presence of the bars is not hard to overlook. The pilots simply make it a personal habit to always engage the flight director whenever they engage the coupler.

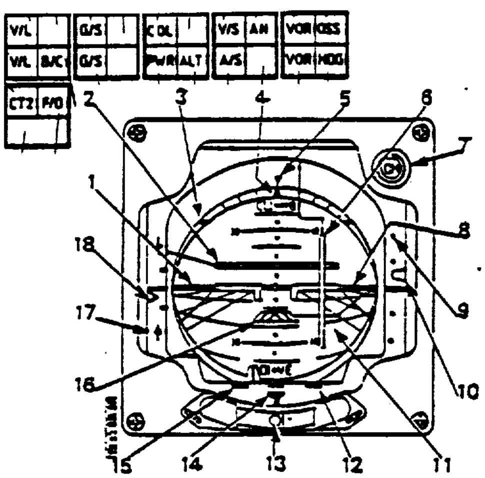

FIGURE 4. Attitude Deviation Indicator

This practice does, however, have one big disadvantage. If the autopilot disengages, due to a malfunction, on purpose, or inadvertently (and it is disengaged inadvertently from time to time), the coupler drops out, but not the flight director. This makes sense because it is useful to have flight direction when the autopilot is out. The problem occurs when the autopilot is switched back on.

It is not difficult to know when the autopilot disengages: one feels the difference in the cyclic at once. The non-flying pilot usually notices the change in the stability of the flight, as well, and if he is alert, he reaches down and re-engages the autopilot within seconds. Both pilots breathe a sigh of relief.

Unfortunately, their problems are not over. For although the autopilot is back on and the flight director command bars are still in view on the ADIs, the coupler is not engaged. The only indication that tells the pilots the green coupler function lights are sending signals to the flight director only and not to the autopilot, is a small, dimly-lit "F/D" light tucked away above the ADIs.

It usually takes some time and perhaps large heading or altitude deviations before the pilots discover that the autopilot coupler functions are not flying the helicopter for them. If this happens during a critical phase of flight, such as during an instrument approach to an oil rig at night, the consequences could be tragic.

"CPL" warning light. Whenever a coupler function fails or is turned off, the "CPL" light on the master annunciator panel and the master "WARN" lights illuminate. Pilots like to have warnings when something fails, but to receive a warning every time something is purposely switched off is counter-productive.

The human factor reason is so obvious that it is difficult to understand how it was overlooked: If a warning light comes on numerous times during every flight,eventually it will be ignored.

The first time a pilot new to the Super Puma switches off a coupler hold function he immediately notices the "CPL" and "WARN" lights illuminating, and, being new to the machine, he logically assumes something has failed. However, by his third or fourth flight, he is already ignoring the "CPL" light or canceling it without thought.

The story about the boy who cried "Wolf!" is a good lesson in human nature which was apparently forgotten when the SFIM designers were working on this part of the CDV 85 four-axis coupler.

Navigation Equipment

NAV-HSI switching panel. Another very confusing part of the Super Puma is the navigation switching panel (FIG. 5). Basically, each pilot has two pointers on the HSI, and he has switches by which he can choose which navigation radios he wants to monitor. There is also a switch that controls the Course Direction Indicator (CDI) which accepts signals from VOR 1 or VOR 2. However, there is an inflexibility in the system in that the autopilot will accept coupled ILS signals only from VOR 2 and only when the right-seat pilot has selected VOR 2 on his CDI and only when the heading select switch is set to "PILOT." This automatically, restricts the pilots' choices if they want to fly a coupled ILS.

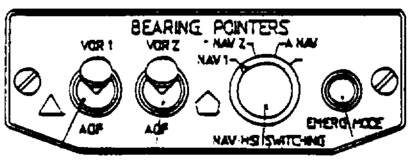

FIGURE 5. NAV-HSI switching panel

The number 1 (green) pointer on both pilots' HSIs takes signals from either VOR 1 or the ADF (or ADF 1 if two are installed). The number 2 (orange) pointer takes signals from VOR 2 and the ADF (or ADF 2 if two are installed).

The confusion occurs because BOTH pointers can indicate either VORs or ADFs and it is common to use both a VOR and an ADF during many VOR and ILS approaches. What can easily happen is that the copilot has the ADF on pointer 1 and the VOR on pointer 2 and the pilot has the opposite indications.

A better system, given the limitations of only two pointers, would be to designate one pointer as the VOR pointer and the other pointer as the ADF pointer, with a switch to reverse these functions in case of a pointer failure. That way both pilots would always know that they have VOR information on the green pointer, for example, and ADF information on the orange pointer. To remove the question of which VOR or ADF is being monitored, the pointers themselves could display a "1" or "2," indicating, respectively, VOR 1 or VOR 2 on the VOR pointer and ADF 1 or ADF 2 on the ADF pointer. The navigation pointers incorporated in many EFIS installations the author has seen are labelled in this manner.

One could monitor two VORs on the same HSI by switching the CDI to one VOR and the VOR pointer to the other. It would not be possible to monitor two ADFs simultaneously on one HSI, but this is a relatively infrequent requirement. (The Helikopter Service Super Pumas are only equipped with one ADF anyway.) If there is a requirement to monitor two ADFs, the pilot could monitor one and the copilot the other, or, as an alternative, either pilot could switch between ADF 1 and ADF 2 every few minutes to check the relative bearings to the NDB stations.

DME selection. It is possible to monitor one of six different DME stations depending on how the switches are set. However, the only indication of which VOR frequency is giving the DME reading is by the position of the switch and a light on the radio itself. The light indicates that the DME is coming from that box (number one or two), but it could be from one of three possible frequencies, one of which may not be displayed, depending on the position of the HOLD switch.

This can and does create so much confusion that Helikopter Service instructors recommend setting the DME function switch to VOR 2 (because this is the only VOR that can be used to fly a coupled ILS approach) and just leaving it there all the time, except in those rare cases when DME information from a second VOR is required. The problem is that there are just too many choices -- too many frequencies from which one can receive DME information. In the heat of an approach or a missed approach, it's easy to forget which DME one is monitoring.

Radio frequency selection. This is a generic problem to many aircraft, not just the Super Puma. Many operators do not have 100% standardized fleets. In fact, there are probably very few operators that have the same radios in all their aircraft. This is obviously a matter of economics that pilots just have to live with.

With most radios, the frequency selected increases when one rotates the knobs clockwise, but on a few the frequencies increase when the knobs are turned counter-clockwise. Some radios allow one to rotate the knob past the highest useable frequency and continue turning to the lowest frequency on the scale, and vice verse. Others stop at the highest and lowest frequencies, making it necessary to turn the knob back the other way. Most two-tiered knobs (like wedding cakes) work so that the lower, bigger knob adjusts the numbers in the left window (therefore the higher numbers) and the higher, smaller knob adjusts the numbers in the right window (therefore the lower numbers); other radios work just the opposite.

It goes without saying that pilots are going to have trouble tuning frequencies when they have to use different radio sets. This may seem like a relatively small thing, and most of the time it is, but it can be a time-waster. In the worst case a pilot may accidently set the wrong frequency, not have time to check the windows, and miss a critical radio call. Standardizing how frequencies are dialed in will eliminate one area in the cockpit that is prone to mistakes.

Landing Lights

When the search light switch in the Super Puma is pushed down, the search light moves up. When the switch is pushed up, the search light moves down.

This is exactly opposite from the way the moveable search light in the S-61 and Bell 212 work and since all Helikopter Service pilots flew one or both of these helicopters before transitioning to the Super Puma, it's no wonder that this causes difficulty.

Most of the time landing lights are not needed until short final when they need to be positioned quickly and accurately. When the light moves in the opposite direction from what is expected, it's not only irritating, but potentially dangerous as well.

As a rule, moveable landing and search lights should move up when the switch is pushed up and move down when the switch is pushed down.

Intercom Switching

The pilot's and co-pilot's intercom switches are two-position switches, "NORM" and "EMER". In the normal position, the voice-actuated system works, which is an extremely good system to use. The emergency position is there in case the normal power supply to the system is lost. When in "EMER," the pilots have to key the microphone switches on the cyclics or the intercom control panel in order to talk to each other.

The intercom system would be better if the need to switch to "EMER" in case of a normal supply failure were eliminated. In other words, once the pilots discover that the voice-actuated system no longer works, all they have to do is use the cyclic or panel microphone switches.

Trouble-shooting an electrical fire is one emergency when the emergency intercom system is needed. Various electrical suppliers must be switched off, including the normal power supply to the intercom and the autopilot. One pilot must therefore concentrate exclusively on flying while the other pilot is trying to isolate the fire. This is no time for communication difficulties. Requiring both pilots to switch to "EMER" just adds an additional burden and stress factor to the emergency.

SOFTWARE FACTORS OF THE AS332L-1 COCKPIT

General

As noted before, software factors include many items, all of them concerned with information. Often, good, well-designed operating procedures and checklists can make up for design faults in the aircraft. For example, with reference to the flashing "OVSPD" light problem, Helikopter Service has a prominent note in the company Emergency Checklist under "Engine Malfunctions," stating that a failed engine should not be re-started if the "OVSPD" light is flashing.

It is not the intention of this paper to try to examine the flight manual, operating procedures, and all other information sources about the Super Puma, but rather to limit the discussion to the information presented to the pilot in the cockpit. In the author's opinion, the "AS332L-1 Super Puma Instruction Manual" is is very well written. However, there are two main problems with the manual, which also apply to the cockpit indications. The first is the occasional inconsistency among terms and the second is occasional poor translations from French to English, including abbreviations. These two problems are probably related in many instances.[6]

An example of the first is the use of both "generator" and "alternator" to describe the same thing in the electrical system. Examples of the second type of problems, translations and abbreviations, are discussed below.

"MGB COOL" Warning Light

The Super Puma main gear box has two lubrication pumps, a normal one and an emergency one. Both pumps are essentially the same and both run continuously. The main differences are (1) the main pump delivers a slightly higher pressure, (2) the input to the emergency pump is positioned below the input to main pump, and (3) the emergency pump system bypasses the transmission oil cooler.

If the main pump stops delivering oil, either due to a leak in the system or failure of the pump itself, the emergency pump will continue to supply oil to the main gear box. The emergency pump bypasses the transmission oil cooler because a leak in the system will most likely be in the plumbing to the oil cooler. The emergency pump lubricates everything in the main gear box, but the oil is no longer cooled. As a consequence, one can expect a gradual rise in transmission oil temperature with a failure of the main pump or a leak.

It's obviously important to warn the pilot that this has happened and the "MGB COOL" light (Fig. 6, #6) serves this function. It is triggered by a pressure switch which senses the drop in pressure in the line downstream of the oil cooler.

The theory is very good and the light works in practice, but the language on the light creates confusion. "MGB COOL" does not mean that the MGB is now cool or will become cool. Quite to the contrary, the oil will now become <u>hotter</u>. Nor

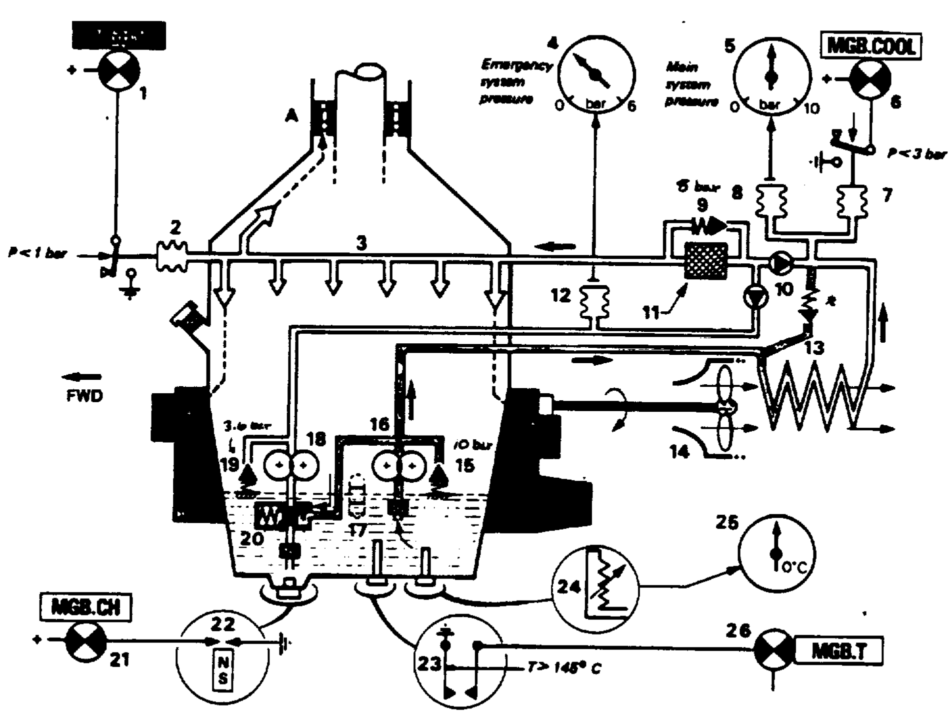

FIGURE 6. Main gear box lubrication system.

does the light mean that the MGB cooler has failed. If the cooler fails, due to a broken drive shaft or shattered fan blades (both of which have happened a number of times), the "MGB COOL" light does not illuminate; what one sees is a rise in MGB temperature and, eventually, a "MGB TEMP" warning light. "MGB COOL" means that the MGB cooler has been bypassed. This is not, however, the most important thing the pilot needs to know at this point, even if he does remember what the light signifies.

The important thing is that the main pump is no longer delivering oil to the system, either because of a failure or a leakage. Therefore, it would seem to make more sense for the light to be labelled so that it better conveys this information, for example, "MGB PUMP." The point is: The wording used on warning lights must be carefully chosen so that the most critical factor of a given malfunction is immediately comprehended.

Hydraulic Panel

The labelling on the hydraulic panel is particularly confusing, even to pilots who have flown the Super Puma for many years (Fig. 7A & 7B). The problem is that the abbreviations are not consistent and this was a result of translating abbreviations from French to English.

On some of the switches, the letter "H" stands for "hand" and on others it stands for "hydraulic." On many of the switches, "H" could stand for either "hand" or "hydraulic." On one switch, "H" stands for both "hand" and "hydraulic."

The correct meanings are as follows:

LH.P = LEFT HAND PRESSURE (low)

LH.LEV = LEFT HAND LEVEL (low)

LH.H.MP = LEFT HAND HYDRAULIC MAIN PUMP (failure)

AP.H.P = AUTOPILOT HYDRAULIC PRESSURE (low)

AUX.HP = AUXILIARY HYDRAULIC PRESSURE (low)

AUX.P = AUXILIARY PUMP (failure)

AUX.P = AUXILIARY PUMP (on/off switch)

RH.P = RIGHT HAND PRESSURE (low)

RH.LEV = RIGHT HAND LEVEL (low)

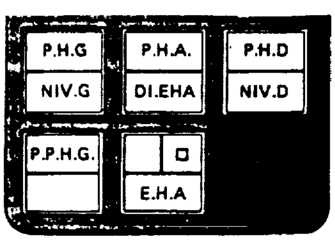

FIGURE 7A. Hydraulic panel with French abbreviations.

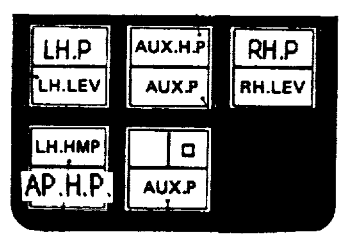

FIGURE 7B. Hydraulic panel with English abbreviations.

The culprits on the English switches are the letters "P" and "H." On some of the switches, the letter "P" stands for "pump" and on other switches it stands for "pressure." On every switch "P" appears, it could logically stand for either "pump" or "pressure."

It's easy to understand how this creates confusion. Anything that does this, particularly during an emergency, is going to increase the stress level and the chances for mistakes. The lesson is obvious: Make all abbreviations readily understandable and consistent.

"THROT" Light

This light indicates that one or both of the fuel flow control levers (FFCL) is not in the "FLIGHT" position, where they normally should be if they are working normally. It's a useful light with an engine failure and subsequent shut-down because it is the only warning light that remains illuminated after the FFCL has been set in the shut-off position. (The "DIFF NG" and "PRESS 1" or "PRESS 2" lights extinguish when the FFCL is in the shut-off position.)

But why is it called the "THROT" light, and not, for example, the "FFCL" light? The term "throttle" is not used anywhere in the Instruction Manual or the Flight Manual. The proper term is "Fuel Flow Control Lever." The use of the word "throttle" and its abbreviation "THROT" is, perhaps, either a carry-over from the days when most helicopters had reciprocating engines and, therefore, throttles (admittedly, some still do) or perhaps it's just another translation problem from French to English.

The point is: Consistency. Items should always be referred to by the same correct name, both in the flight manual and in the cockpit.

Autopilot Panel

The hardware aspects of the autopilot were discussed previously. The software aspects of the panel are actually quite good, with only a few minor exceptions.

To test the basic autopilot system, one moves the test switch from "TEST" to "RUN," meaning, apparently, that one is "running the test."

On the other hand, to test the collective part of the autopilot (the fourth-axis), one moves the test switch from "NORMAL" to "TEST."

Again, it's a small point, but one that is easily corrected.

"RB. SAFE" and "ROT.BR" Lights

The Super Puma has a two-lever rotor brake system with a rotor brake safe lever and a rotor brake lever. It is possible to move the rotor brake lever to the braking position in flight (which obviously should not be done), but it will do nothing more than cause the "ROT.BR" light to illuminate (Fig. 8). Hydraulic pressure to the rotor brake is obtained only when both levers are pushed forward, a sensible system which just about guarantees that the rotor brake won't be engaged inadvertently at the wrong time.

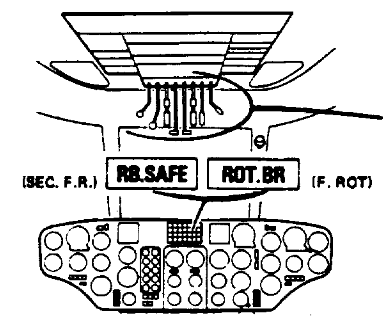

FIGURE 8. "RB. SAFE" AND "ROT.BR" lights

"RB. SAFE" means that the rotor brake safety lever is in the forward position, not, as one may be lead to suspect, that the rotor brake is safe. Actually, one could argue that with the safety lever in the forward position, the rotor brake system is unsafe because, now, if the rotor brake lever is moved forward, braking pressure will be applied to the rotor system. In effect, moving the rotor brake safety lever forward arms the rotor brake system.

So why not label the "RB. SAFE" light "RB ARM?" One could also change the "ROT.BR" light to "RB ON" to make the abbreviation of "rotor brake" consistent.

Heater Distributor Valve Control

The heater has a three-position distributor valve control lever so that the pilots can choose where they want the heat directed. In the forward position, the heat is divided between the cockpit and the autopilot; in the middle position, heat goes to the cockpit, the autopilot, and the cabin; in the aft position, all heat distribution to the aircraft is cut off. The problem with the heater lies in the fact that the distributor valve control lever has been poorly labelled.

The forward position is labelled "COCKPIT POSTE PILOTE." This looks like a blending of English and French -- it probably means the cockpit will be heated. But it says nothing about the autopilot which is also heated.

The middle position is labelled "O." A person who knows a little French might conclude that "O" is an abbreviation for "ouvert" which means "open." But what is being heated with the switch open? There's no way to determine this from the labelling of the switch. On the other hand, a person who knows no French might think the "O" (oh) is a "0" (zero) and that it means the heater is off or closed.

The aft position is labelled vertically "F C." Again, a French speaker might assume the "F" stands for "fermé" which means "closed" and the "C" might be an English abbreviation for "closed." Then again, both letters could be either French abbreviations or English abbreviations. It's very hard to tell.

This may seem like a small thing again; after all, it's only the heater switch. But it is also confusing, annoying, and totally unnecessary. With only a bit more thought and effort, the lever could have been labelled so that the function of the three positions were obvious.

SPURIOUS WARNINGS

As was mentioned before concerning the "CPL" light illuminating every time a coupler function is switched off, continuous unnecessary warnings eventually are ignored. Complacency with respect to the warning is the result. In some aircraft, pilots have gone so far as to pull circuit breakers for certain specific warning lights because they were so prone to false warnings. MGB chip warning lights are notorious examples.

Sophisticated electronic systems seem to be all too prone to spurious warnings. The numerous landing gear position switches in the Super Puma are particularly sensitive, and if it weren't for the aircraft's emergency electrical and hydraulic extension possibilities, there would be a lot of gear-up landings at Helikopter Service. These switches are not, however, just a problem for the landing gear, but also for all the auxiliary equipment which receive "GROUND" or "FLIGHT" signals from these same switches.

For example, a common problem with the Super Puma is for the area navigation system (be it VLF/OMEGA, DECCA, LORAN, or whatever) to "freeze up" in flight. The solution is to re-cycle the landing gear. The cause is the loss of the "FLIGHT" signal to the area nav system because one of the landing gear has moved out of position far enough to open a switch which should have been closed.

Another related problem concerns the autopilot. Once the author found it impossible to run the autopilot test, even though the switch was moved from "TEST" to "RUN" several times. All the functions worked, but the test just wouldn't run. A mechanic was notified and he immediately realized the problem was a position switch in the nose gear. He grabbed a tow bar, jiggled the nose wheel, and the autopilot test worked as designed.

Incorrect fire warning system tests during start-up are another headache. Mechanics have changed system control cards, wiring harnesses, and fire detectors, but usually the problem is simply moisture. Most of the time the system will test properly after the engines are started and everything is allowed to warm up and dry out.

The point is that pilots quickly loose faith in a warning system if it continually gives false warnings. When a warning system cries "Wolf!" all the time when there is no wolf, the one time there really is a wolf at the door, it may be ignored. The increased use of electronics and computers in helicopters promises numerous advantages for the pilots, but the systems must be constructed so that they are not adversely affected by the environment.

FUTURE CONSIDERATIONS

"New technologies incorporating multiple redundancy and fail-safe concepts are becoming so reliable that, in future years, the proportion of human factor accidents may reach 100 percent simply because the total, irrecoverable failure of machine components of the man-aircraft system will be eliminated."

Dr. Robert B. Lee
Australian Bureau of Air Safety Investigation[7]

"The Space Invader-playing kids of today will be the fighter and bomber pilots of tomorrow."

Ronald Reagan
40th President of the United States

Even though former President Reagan didn't mention helicopter pilots in the above quote, they certainly must be included. What is just as certain is that his prediction is already coming true.

How will this effect human factor problems in the cockpit?

Not more than ten or fifteen years ago, the space and aircraft industries were the epitome of high-tech. In many ways, they still are, but since the advent of inexpensive micro-chips, "smart" machines are now commonplace in most homes. Today, the gap between sophisticated aircraft and sophisticated household machines has narrowed. Entire houses can now be controlled by a central computer. In late 1988, the Electronic Industries Association/ Consumer Electronics Group announced a new wiring standard called the Consumer Electronics Bus which will enable microprocessor-equipped appliances built by one company to communicate with those built by another.[8]

This means that more and more people will use sophisticated electronic and computer-controlled devices on a daily basis. Today, many children learn to operate machines even before they can read.[9] At age four, the author's youngest son knew how to operate the remote controls of a video cassette recorder and television, find and play games on a Macintosh computer, use various cassette players, and heat food in a microwave oven. Operating machines is second nature to him.

Aircraft designers will have a new human factor element to consider. Instead of the automobile, electronic, and other industries mimicking the designs of equipment found in aircraft, the aircraft manufacturers may find themselves copying panel designs from these industries in order to avoid human factor problems in the cockpit. This is not to say that aircraft will loose their place on the cutting edge of technology, but that aircraft designers will have to be more aware of the designs of equipment made by other industries.

For example, affordable, hand-held GPS systems are now available for less than $1000 from a number of manufacturers. It won't be long before a dashboard-mounted GPS becomes a common option in automobiles and trucks. If the GPS receivers pilots find in their aircraft are very dissimilar from these car systems and hand-helds, human factor errors will occur.

In the past, pilots had to contend with transfer of learning problems between their airplanes and their automobiles.[10] These problems will seem minor to the pilots of future generations who will have to contend with transfer of learning problems between their aircraft and their cars, their computers, their home entertainment systems, and numerous other gadgets, appliances, and machines, some of which have yet to be invented.

There will be international "standards" developed and accepted, sometimes by agreements and official decrees, but perhaps more often by the company that is able to sell the most of a particular product first. If a similar machine does not fit the accepted "norm" or the standard that people have become accustomed to, problems will arise.

A human factors problem occurred when Helikopter Service installed a new security system in the main office and hanger. Like the old system, the new one required the use of magnetic-strip identity cards. The old system required one to insert the card in the controller and punch in a four-digit code before the door would open. The new system required that the code be punched in first, then the card inserted. If the card was inserted first and then the code punched in, as with the old system, a red light blinked indicating something was wrong.

On the first day, hardly anyone could get into the building. Even though instructions had been distributed beforehand, few bothered to read them, assuming wrongly that the new system worked the same way as the old one. Most people thought there was something wrong with their card or their code. The problem was the system itself; the fault was that of the engineer who had not realized that a "standard" for card-and-code door opening systems had already been established at the company.

There may have to be a radical change in the way aircraft are designed. In the past, the machine was foremost. The goal was to make the machine work and if a switch or lever was in an awkward position for the pilot, then he just had to adapt to it. Fortunately, this attitude has changed a great deal since World War II and aircraft designers spend much more attention to ergonomic factors inside the cockpit.

In the future, however, designers will also have to look outside the cockpit, at the numerous other sophisticated machines that are becoming or are already commonplace, when considering human factors problems.

Everything in the cockpit will have to be considered in this light. From the simplest mechanical things, such as the way the seats are adjusted, to the most sophisticated computer-driven systems. Designers will have to stay up-to-date with currently accepted standards in the "outside world." Are computer pull-down menus and "windows" so widespread that they should be considered standards to be used in the cockpit? Should the "QWERTY" keyboard found on typewriters or the keypad used on touch-tone telephones be the standard for aircraft navigation and computer systems? Should the clock be digital or analog, or both? Should the artificial feel in a fly-by-wire control stick have the same "feel" as a Nintendo joystick? These are the kinds of questions that must be constantly and continually asked.

To help answer questions like these, manufacturers must establish, promote, and use an effective feedback system so that ideas and suggestions from line pilots in the field can be obtained on a regular basis.

Every successful company believes it is "the man on the shop floor" who best knows how to do his job and who has the most useful suggestions about how to do it better. Good companies solicit information from every level.

In the author's experience, aviation companies are often very conservative and many even have military-like organizations. Information in military hierarchies goes up and down the chain of command, although it usually flows down a lot easier than it goes up. If the chief pilot or chief of maintenance does not agree with a line pilot's or mechanic's suggestion, the idea stops there and never gets to the manufacturer where it might have been accepted. The only exception is in the case of an accident. Then people are listened to.

A reporting system connecting line pilots directly to manufacturers would be an excellent way to get feedback about present and future cockpits.[11]

CONCLUSIONS

The author readily concedes the subjective nature of this paper. However, given the fact that the very nature of the applied technology of human factors presupposes a degree of subjectivity, the author hopes his departure from the scientific method will not cause his conclusions to be summarily disregarded. In lieu of a feedback system described above, a forum such as this is one of the few ways a line pilot can make his observations and opinions known to people who can make a difference.

1. Flashing warning lights should only be used for the most serious of malfunctions; taking the proper corrective action and removing the hazard, should be the only possible way to extinguish a flashing warning light.

2. Extreme care must be used when designing a switch to function as both a switch and a warning light. One should not assume that a task people can do under normal conditions will still be error-free during an emergency.

3. Autopilot functions should be annunciated on the flight instrument relevant to each particular function.

4. All autopilot functions should be fully controllable from each seat. Single-pilot IFR capability is great, but it should be available to both captain and copilot alike.

5. It should not be possible for the autopilot to capture the glide slope portion of an instrument landing system until the localizer is captured.

6. Warning lights that illuminate every time a minor item, such as an autopilot coupler function, is switched off have a tendency to be ignored by pilots after a few hours of experience in the aircraft.

7. All radio frequency selectors should rotate the same direction: clockwise to increase frequency; counter-clockwise to decrease.

8. Moveable landing or search lights should move up when the switch is moved up and move down when the switch is moved down.

9. The language used on warning lights and switches should be consistent with the wording used in the flight manual, checklists, and other related material; the wording must be carefully chosen so that the most critical factor of a given malfunction is immediately comprehended; abbreviations should be consistent, logical, and easily interpreted; translations to other languages must be very carefully checked for correct meanings.

10. Electronic and computer-based systems must be constructed so they are not adversely affected by the environment.

11. Cockpit designers must look outside the cockpit, at the numerous other sophisticated machines that are becoming or are already commonplace, when considering human factors problems that may occur in the cockpit.

12. Manufacturers should establish, promote, and use an effective feedback system so that ideas and suggestions from professional pilots are obtained on a regular basis.

FINAL THOUGHT

If Dr. Lee's predictions about the proportion of human factor accidents reaching 100% is right, then constant awareness of and attention to human factor problems by everyone involved with the design and operation of aircraft will be the only way to prevent aircraft accidents in the future.

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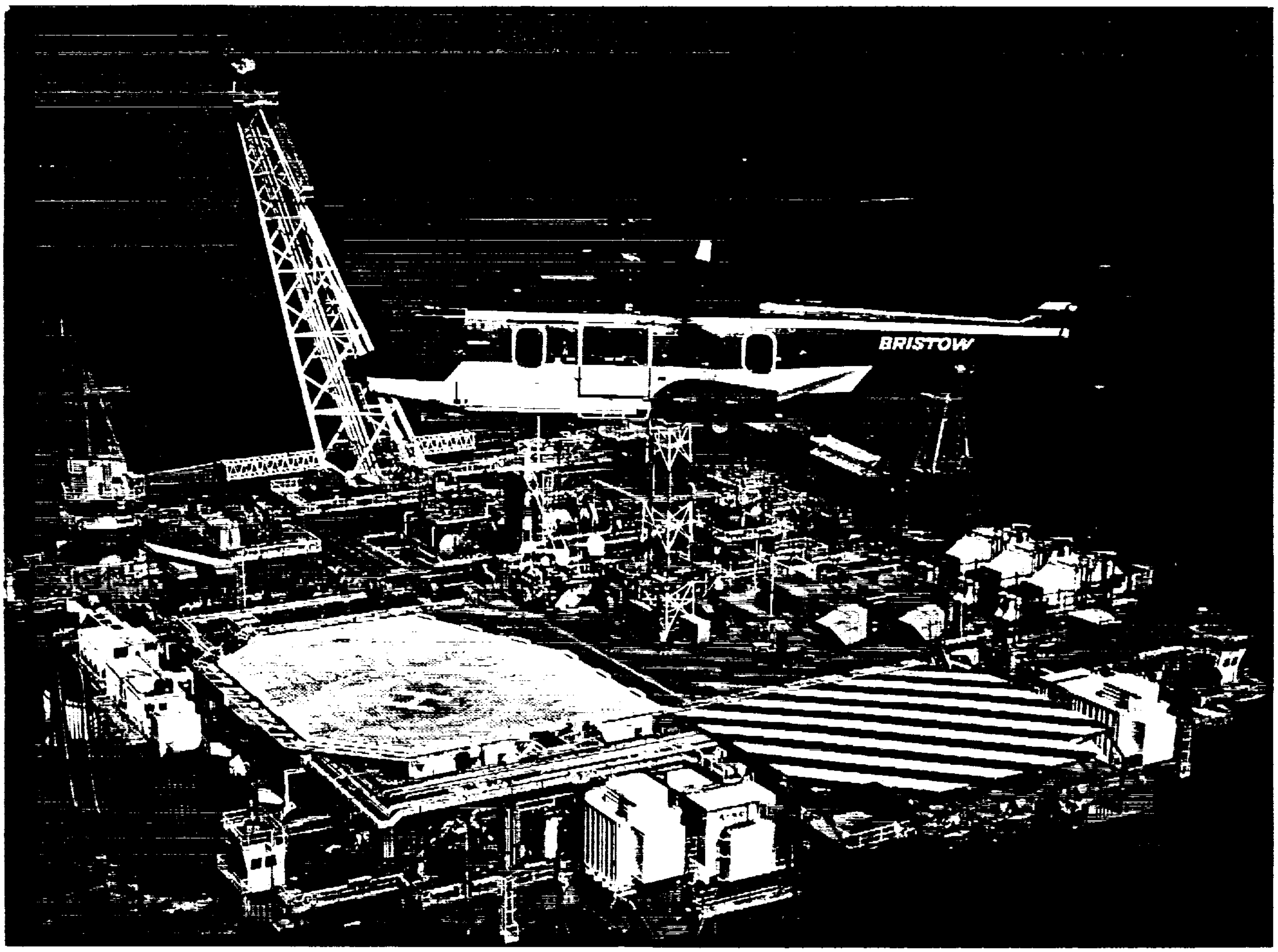

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